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Cost-effectiveness of health system strategies for older patients with malnutrition presenting in hospital

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Master of Health Services - Research

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THESIS CERTIFICATION

I, Bianca Suesse, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Master of Health Services - Research, in the School of Accounting, Economics & Finance, Faculty of Business, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

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ABSTRACT

Malnutrition in the older adults is a hidden epidemic in many affluent regions of the world, including Australia. An estimated 30-43% of the aged (over 65) population in Australian acute and rehabilitation hospitals are malnourished. It is often underdiagnosed and undertreated. Older adults are at an increased risk of not getting the right balance of nutrients and calories needed to stay healthy. This is because as they age their dietary needs change as do their self-care ability and living arrangements, while the older adults are also more likely to develop malnutrition with acute or chronic diseases (disease-related malnutrition). Malnutrition often results in an impaired immune system and recovery from disease, higher morbidity, care needs and hospital readmission rates, longer hospitalisations, and a lower quality of life. The clinical and health system consequences of malnutrition point to far reaching downstream health and aged care needs and cost consequences of failing to adequately treat malnutrition in the older population.

The objective of this thesis is to inform health and aged care decision makers about the cost-effectiveness of an integrated hospital care and discharge strategy aimed at improving health system care and cost impacts across care settings for malnourished older patients presenting in acute care hospitals in Australia. The thesis in addressing this undertakes evidence synthesis combining health economic analysis of nutritional epidemiological studies in older patients with or at risk of malnutrition in the Australian acute hospital setting with trial evidence of the Re-Engineered discharge (RED) model of care. Importantly for the older population with or at risk of malnutrition, the RED care model has been shown to reduce rehospitalisation while addressing care continuity across the health and aged care system more generally.

Health economic analysis of epidemiological data in this thesis identifies that poor nutritional status of older acute care patients in addition to being highly prevalent jointly predicts adverse clinical outcomes, mortality, readmission rates and greater use of higher level aged care at 12 months follow-up. Addressing hospital malnutrition with the RED care model, an additional direct cost of applying the RED care model (AUD 57) to older patient populations in Australia who have high care costs, are expected to be more than offset by many order of magnitude greater hospital and aged care cost reductions over the period of one year following an index admission. In a conservative base case, the RED care model (AUD 9,200) has a substantial expected net cost saving of more than AUD 4,000 per older patient over usual care practice in Australia (AUD 13,200), attributable to reduced hospital readmissions at 12 months. These costs savings extending to an estimated AUD 5,200 where aged care impacts are additionally allowed for in Australian usual care (AUD 19,600) and the RED care model (AUD 14,400). RED is also modelled in sensitivity analysis to have potential for an absolute 2.0 percentage point overall increase in survival rate, from 87.1% with usual care to 89.1% with the RED care model for survival benefits expected given nutritional status improvement potential across care settings with RED in older acute care patients.

In summary, the RED care model for older patients hospitalised with malnutrition is shown to reduce health and aged care system costs in the process of providing more appropriate nutrition and aged care across the care continuum, in hospital, at discharge and beyond, with potential for associated better health outcomes. More generally, for current health and aged care policies in older populations, it provides a highly cost-effective model enabling appropriate linkage between hospital and primary care providers in the community and aged care, providing the environment for successful integrated care and aging.

Key words: Malnutrition, older adults, hospital, post-discharge, primary care provider, aged care, Re-Engineered discharge (RED), cost-effectiveness modelling, nutrition economics

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ABBREVIATIONS

AR	At risk of malnutrition
CEA	Cost-effectiveness analysis
DAA	Dietitian Association Australia
DRG	Diagnosis Related Group
GP	General Practitioner
HLC	High level care (nursing home)
INB	Incremental net benefit
JOI	Jurisdiction of interest
LLC	Low level care (hostel)
MDC	Major Disease Classification
MN	Malnourished
MNA	Mini Nutritional Assessment
MNA-SF	Mini Nutritional Assessment-Short Form
MST	Malnutrition Screening Tool
NCB	Net clinical benefit (ΔE)
NM	Not malnourished
OR	Odds ratio
PCP	Primary care provider
RCT	Randomised controlled trial
RED	Re-Engineered Discharge
RR	Relative risk
WHO	World Health Organisation
WN	Well-nourished

1 INTRODUCTION

1.1 Clinical, epidemiological and economic aspects of malnutrition

Stratton et al. (2003) provides a widely used definition of malnutrition as: 'A state of nutrition in which a deficiency, excess or imbalance of energy, protein, and other nutrients causes measurable adverse effects on tissue/body form (body shape, size and composition) and function, and clinical outcome'. Thus the term malnutrition includes both undernutrition which is common in many low income countries and in hospitalised populations, as well as overnutrition (excess energy) that has reached epidemic proportions in many affluent regions of the world (Barker et al. 2011). In this thesis, the term malnutrition is used in the context of undernutrition seen in aged populations. In the 21st century, hospitals in high income countries have observed a shift from malnutrition traditionally associated with inadequate access to food to disease-related malnutrition, caused by an underlying acute or chronic disease. Disease-related malnutrition is often not immediately detectable and therefore often underdiagnosed and left untreated in many hospital inpatients as well as those living in the community (Kondrup et al. 2002, Bavelaar et al. 2008, van Nie-Viesser et al. 2009, Jensen et al. 2010). This form of malnutrition occurs quite often in vulnerable populations, particularly older adults who may have special nutritional needs to meet their health and social circumstances (Russell & Elia 2009, DAA 2017). Disease-related malnutrition itself has been defined as a serious medical condition frequently developing during hospitalisation (Correia and Waitzberg 2003, Alvarez-Hernandez et al. 2012).

In Australia, disease-related malnutrition is a major public health problem amongst hospitalised patients and is referred to as the silent epidemic (DAA, 2017) or the 'skeleton in the hospital closet' (Ferguson 2001, Charlton 2010). The prevalence of malnutrition in older Australians admitted to both acute and rehabilitation hospitals has remained high for some time, with an estimated 30-43% of patients in this age group being overtly malnourished, and an additional 52% considered to be at risk of malnutrition. Malnutrition also occurs frequently in residential aged care facilities, with reported prevalence figures for malnourished and/or at risk ranging between 32% and 72% (Middleton et al. 2001; Lazarus and Hamlyn 2005; Banks et al. 2007; Charlton et al. 2010). Worldwide, the malnutrition rates in hospital settings are similar to Australia. In acute hospitals, this ranges from 20% to 50% (Barker et al. 2011). Of serious concern is the fact that most of these malnourished or at-risk frail older adults are discharged home without dietary consideration (assessment or subsequent care planning actions where appropriate), often leading to a downward spiral of ill health and a high chance of later hospital readmission, in an even more compromised health status (Charlton et al. 2013).

The Dietitians Association of Australia (DAA) endorses five validated nutritional screening instruments and three nutrition assessment tools that are applicable for use in the acute hospital setting to identify malnourished and at risk patients (Watterson et al. 2009). The Mini Nutritional Assessment (MNA) is the most extensively used and reliable tool internationally to determine malnutrition, and was specifically developed for older patients (>65 years) in hospitals, nursing homes and the community (Bauer et al. 2008). This 18-item assessment tool considers anthropometrical, medical, lifestyle, dietary and psychosocial factors in a points-based scoring system to determine if a patient is malnourished or at risk of malnutrition. Nutritional screening practices in Australian hospitals, both from 1998 (Ferguson and Capra 1998) and current nutrition care practice in acute care hospitals (Agarwal et al. 2012a) and reports by dietitians in the Illawarra, indicate that not all older patients are screened for malnutrition on admission in acute settings. Hence many of these patients with malnutrition are not identified nor referred for nutritional assessment and treatment. In countries like the United States, the United Kingdom, the Netherlands and parts of Denmark, nutrition risk screening on patient admission is mandatory for hospital accreditation (Elia 2009). According to the NSW Nutrition Care Policy, the basis of the 15 'National Standards' (EQuIPNational guidelines), nutritional screening is deemed as mandatory (ACHS 2017). However, many hospitals are not currently meeting this standard (Agarwal et al. 2012a, personal communication with clinical staff, 2017).

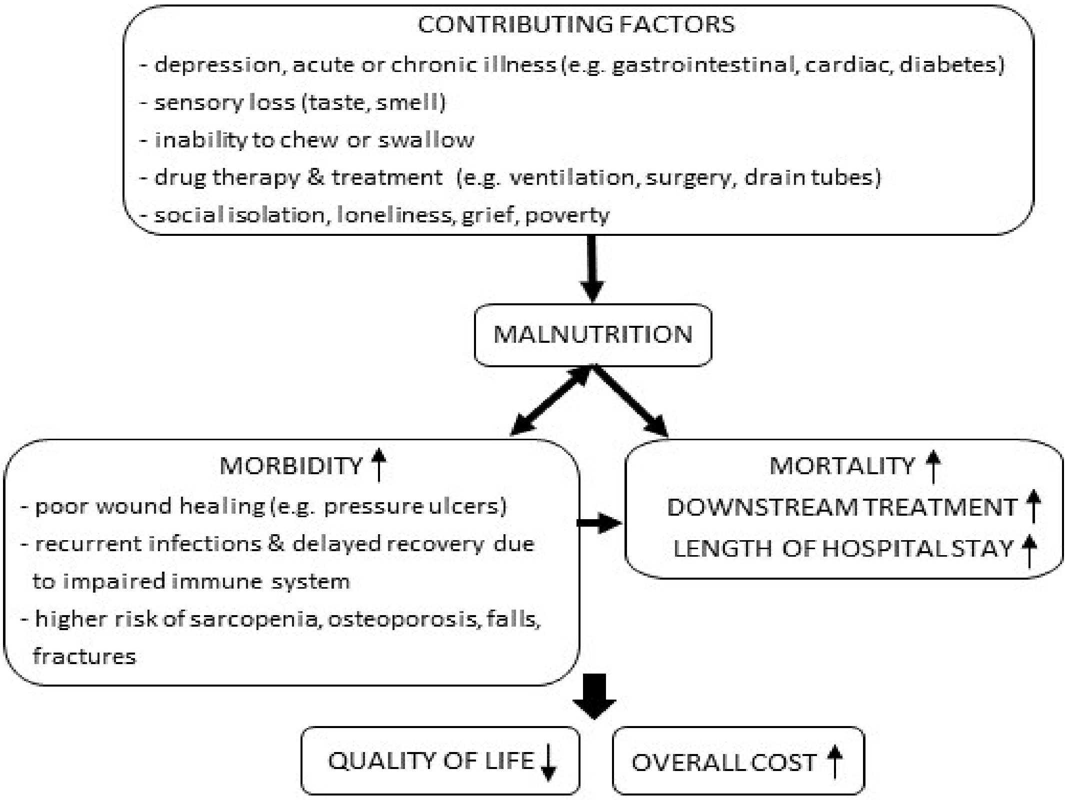
In acute care patients, malnutrition can be caused by sensory loss (taste, smell) and eating difficulties of the older adults, distaste for hospital food and subsequent food abstention, disease pain, drug therapy, gastrointestinal, metabolic and cognitive problems like diarrhea, inflammatory bowel disease, bowel resection, infections, hyper metabolism after trauma, treatment (e.g. surgery, ventilation, drain tubes), cancer, dementia, depression, delirium and socio-economic factors e.g. grief, loneliness, high care dependence, anxiety and poverty (Barker et al. 2011). An extensive review by Stratton et al. (2003) identifies that malnutrition is associated with cellular, physiological and psychological declines in health, resulting in higher risk of falls, fractures and adverse outcomes related to chronic diseases. Studies have shown that disease-related malnutrition can have various consequences: impaired immune function and wound healing, increased risk of infections and pressure ulcers, loss of body weight (muscle and fat mass) and strength, hair loss, pale skin, increased risk of falls, decreased respiratory and cardiac function and atrophy of visceral organs, compromised intestinal absorption of nutrients, thermoregulation and renal function (Kubrak and Jensen 2007, Barker et al. 2011). Thus, the presence of malnutrition may impair patient recovery from disease or injury and lead to greater morbidity, lower quality of life, increased length of hospital stay and increased healthcare costs (Kagansky et al. 2005, Brantervik et al. 2005, Halfens et al. 2012). Studies by Charlton et al. (2010, 2013) show that malnutrition assessed with validated instruments by hospital dietitians predicted a greater than threefold risk of in-hospital mortality over 12 months follow-up in older Australians (aged 65 and older) presenting in hospital, after accounting for underlying illness and age. Several studies have also found that malnourished patients have higher rates of medical prescriptions than their well-nourished counterparts (Pirlich et al. 2006, Norman et al. 2008, Álvarez-Hernandez et al. 2012).

In the context of ageing populations, as the baby boomer cohort (born 1946 – 1964) become 65 years and older, most western countries are expected to experience a dramatic increase in the proportion of frail older adults and their associated health care demands. While in 2010, about 3.3 million people (13.5% of the Australian population) were aged 65 years and over, the number of older Australians is expected to grow to 8.7 million (22% of the population) by 2056 (ABS 2011). In 2014-15, 41% of adults aged 65 years and older received hospital bed admitted patient care in Australia (AIHW 2017b). A high proportion of older patients also occupy hospital beds due to either not being able to be sent home or while waiting for places in aged care, which represents a large unnecessary financial burden on the public hospital and health system (Alexander 2015). Hence, there is significant potential for cost savings across health and aged care systems in addressing hospital malnutrition while treating an underlying disease. Strategies that help address malnutrition in older inpatients include routine screening, diagnosis and implementation of medical nutrition therapy, i.e. oral nutritional supplements, enteral or parenteral nutrition in high-risk patient populations (Waitzberg and Baxter 2004) and arrangement of appropriate post-discharge care.

Nevertheless, evidence related to strategies for addressing malnutrition in older adults has been almost exclusively focused on medical nutrition therapy. Evidence from systematic reviews and meta-analyses have shown that nutritional support, in particular oral nutritional supplements, are effective in high-risk patients such as older adults with disease-related malnutrition across a wide range of disease conditions, including orthopedic, chronic obstructive airways disease, oncology and surgical specialties. Nutrition care guidelines worldwide, including the NSW health nutrition care policy (ACHS 2017), advise that nutrient needs in patients should be met with regular and fresh food, if clinically possible, to improve the nutrient intake. Only when patients are unable to consume adequate nutrition orally should medical nutrition therapy be considered (Correia et al. 2014). Improvement of nutritional status can lower mortality and complication rates, reduce infections as well as decrease the risk of developing pressure ulcers, and thus increase the patient's quality of life (Potter et al. 2001, Stratton et al. 2005, Stratton and Elia 2007).

Malnutrition not only has adverse consequences for the patients' health at a cellular, physical and psychological level, depending on age, gender, underlying illness and nutritional intake (Barker et al. 2011), but also has negative economic consequences for the health care system. Figure 1.1. summarises contributing factors, consequences and outcomes for both patients and the health care system associated with malnutrition. It seems apparent when researching the relationship between malnutrition and the consequences for patients and the health care system that benefits to individuals and hospitals exist if malnutrition is correctly identified, treated and appropriate care arrangements and provision beyond hospital discharge for malnutrition are made. Therefore, nutritional screening, monitoring in the acute hospital setting and care reporting over time is suggested to be essential for improving patient health outcomes and lowering health system costs.

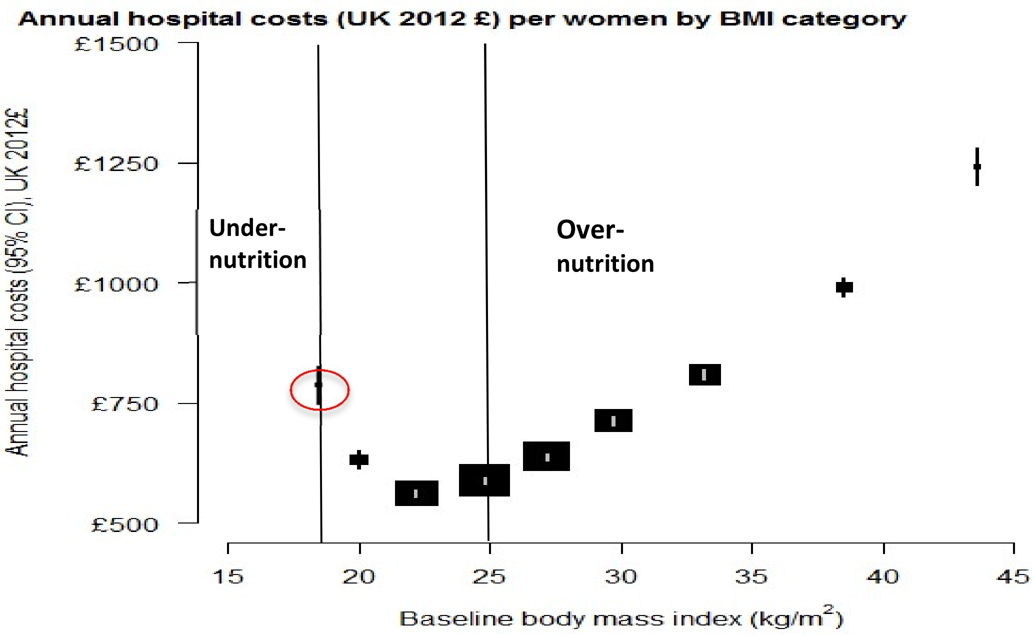
Fig. 1.1 Causes, consequences and outcomes associated with malnutrition in older adults



Adapted from Flanagan et al. (2012) and Fight Malnutrition (2017)

Amaral et al. (2007) estimated that the within-admission cost of treating a nutritionally-at-risk patient is 20% higher than the average cost for an age-matched patient with similar underlying disease. Annual malnutrition-related costs in the UK have been estimated to exceed EUR 9.2 billion, much of which is associated with increasing healthcare use (general practitioner (GP) visits, hospital length of stay) as well as downstream impacts such as the need for nursing home care and hospital readmission (Elia and Stratton 2009). Disease-related malnutrition is estimated to affect 33 million patients in Europe and annually costs those governments up to EUR 170 billion (Ljungqvist and Man 2009). This points to downstream health consequences and substantial costs and hence health system efficiency concerns of failing to adequately treat malnutrition, not only for an older adults' quality of life but also for budget- and resource-constrained health and aged care systems, and the broader social system. While Kent et al. (2017) provided valuable estimates on total hospital costs associated with overweight and obesity in 1.1 million older women in England compared to the well-nourished, their evidence also point to higher costs of patients with undernutrition (Fig. 1.2). The U-shaped curve in Fig. 1.2 shows significant potential benefits of addressing undernutrition, as is the case for addressing overnutrition in older populations, in terms of the associated high costs of both of these conditions that place a burden on the health system. The BMI ranges used for underweight (<18.5 kg/m^2) and overweight (25-30 kg/m^2) indicating undernutrition and overnutrition are those recommended by the World Health Organisation (WHO) (WHO 2000). Very little research has focused on downstream health care system costs and none that include aged care costs of alternative strategies for undernourished ill older patients aged 65 years and older.

Fig. 1.2 Hospital costs relationship with BMI in older women aged 50-64 - higher costs in under- and overnutrition



Adapted from Kent et al. 2017

1.2 Social relevance and scope of this research

Malnutrition in Australian hospitals is a continuing major health concern as the increasingly aging population presents with multiple medical problems placing them at higher risk of malnutrition. Despite the high prevalence of malnutrition, especially in the acute hospital setting, its substantial burden on both patients and health care costs, and the emerging knowledge of how best to prevent and manage the condition, attention to a patient's nutritional status seems to have low medical priority (Charlton et al. 2013, Charlton & Walton 2015). According to over 150 prospective clinical trials and meta-analyses, early nutritional intervention results in significantly shorter hospital stays and reduced health care costs (Loeser 2001, Stratton et al. 2003, Stratton & Elia 2007, Russell 2007). An Australian research study on malnutrition in older acute care patients by Charlton and colleagues (2013) pointed to malnutrition screening using a validated nutritional screening tool as an important first step towards better awareness of the problem, but pointed out that if used in isolation would be unlikely to improve the nutritional status of older adults. That study also highlighted that those characterised as being at risk of malnutrition (rather than overtly malnourished) may benefit most from early implementation of nutritional therapy.

The 12-month follow-up evidence (Charlton et al. 2013) also pointed out that malnourished older patients, presenting in hospital, need education on the care processes to address malnutrition and on the social determinants, with environmental and care solutions in their home or community. Research is required to best inform policy makers of the health and aged care system about impacts of, and options to manage malnutrition of older populations presenting in hospitals.

Malnutrition amongst older populations at hospital admission is associated with higher readmission rates and health and aged care costs downstream over time (Sharma et al. 2017), related to inadequate nutritional screening, diagnosis and care, but also lack of care coordination during patient transitions from hospital to post hospital care settings. Given the short hospitalisation periods and subsequent reduced recovery times for often quite dependent older patients, a model that connects within and post hospital health care settings is needed to address this issue. Based on Charlton's study (2013), interventions that improve the older patient's nutritional status in hospital as well as in the post-discharge community setting are required to reduce the risk for adverse clinical outcomes.

Health economics advice needs to take into account a system-wide big picture perspective of health policy impacts allowing for system wide costs and effects. Public provision health systems such as Medicare with universal access to necessary care have been shown to be more effective and efficient as well as equitable based on strong evidence internationally (OECD 2013, Davis 2014). In general, health and aged care systems are increasingly going to face challenges with an increasing aging population, and require system reform to enable successful baby boomer ageing without breaking the budget. More needs to be done to facilitate self- and informal care in the community and invested in programs for older adults that integrate care across the health system linking acute and GP/community care in particular (Kalache 2013, Phillipson 2016, Eckermann 2017).

The policy aim of the current research project is to better inform health and aged care decision makers about a comprehensive and integrated hospital care and discharge model to improve health system care and cost impacts for older populations with malnutrition presenting in hospitals. The high malnutrition prevalence in the older patient population of the study hospital as well as the associated increased risk of mortality and increased length of hospital stay within 12 months in malnourished and nutritionally at-risk compared to well-nourished patients provides the natural history basis for this usual care cost-effectiveness comparison.

1.3 Outline of this thesis

Chapter 2 presents the *Literature Review* of the thesis. The following topics are covered in the literature review: health economics and nutrition, decision analytic modelling and cost-effectiveness analysis (CEA), hospital to health system impacts of malnutrition, identification and treatment of malnourished older patients as well as issues with in-hospital, discharge and aged care in the aging population.

Chapter 3 presents the *Methodology* based on the research questions and the theoretical framework.

Chapter 4 presents the *Results* describing the natural history of the older population in the acute care setting as well as comparing the summary statistics by nutritional status and disease-related groups with the existing within study clinical analysis. It also presents the results comparing and analysing usual care versus an alternative hospital care and discharge strategy for malnourished older patients presenting in the acute hospital setting.

Chapter 5 presents the *Discussion* of the thesis where strengths, limitations, policy implications and future research for the health care system by adapting the alternative hospital care and discharge strategy are considered.

Chapter 6 presents the thesis *Conclusion*.

2 LITERATURE REVIEW

2.1 Health economics and nutrition

Health economics is defined as ‘a branch of economics ‘concerned with the optimum use of scarce economic resources for the care of the sick and the promotion of health, taking into account competing uses for these resources’ (Mushkin 1958). More generally the discipline aims to best inform joint research, reimbursement and regulatory decisions in budget-constrained health care and social systems (Eckermann 2017). In this thesis, health economic analyses are concerned with a complex public health issue of malnourished ill older patient populations and alternative interventions and policies considering their downstream health and cost impacts. Public health care systems are confronted by scarce resources in attempting to satisfy the health needs of populations over time. In the context of an aging baby boomer cohort, to meet aged population needs and preferences with limited resources, societal decision-making requires stringent consideration of opportunity costs in their decision-making process when involving new innovative medical technologies or alongside better use of existing therapies in optimising health system effects (Eckermann 2017).

The first health economic assessments informing reimbursement decisions in Australia were undertaken in the early 1990’s, initially on pharmaceutical products, and are well-documented in national pharmacoeconomic guidelines (Hutton 2012). These guidelines have been adopted and adapted for medical services and healthcare technologies such as medical devices, while more recently, they have also been adapted to consider food and medical nutrition (Freijer et al. 2015). Health care decision-makers have realised that nutrition plays an important role in lifestyle-related disorders. A new discipline has emerged from the nutrition and health economics discipline, called nutrition economics, “dedicated to researching and characterising health and economic outcomes in nutrition for the benefit of society” (Lenoir-Wijnkoop et al. 2011, Freijer et al. 2015). Nutrition economics studies evaluate relationships between nutrition, health, quality of life while considering the costs of health impacts and treatment, both for the individual and at the level of the health care system. Most importantly for decision making, they consider costs and effects of strategies aimed at helping to drive changes in nutritional behaviour in our society (Nuijten and Lenoir-Wijnkoop 2011). Such analysis can explore health and health system cost consequences of nutrient deficiencies at every period of life, but need to consider alternative strategies in order to reduce disease risks, boost recovery and generally make better informed decisions about cost-effective choices across alternative nutrition and dietary care for individuals and populations. In other words, better population nutrition can improve health, but may also contribute to the cost-effectiveness and sustainability of health care systems (Nuijten 2015).

There is not yet specific or systematic methodology that can be applied to decision analytic modelling in nutrition economics. Such methods are required to assess the effect and cost impacts of both the nutrition interventions and their downstream consequences for the individual, the health care setting (especially when transitioning from the hospital to the community) and society as a whole (Freijer et al. 2015). There are various types of health economic modelling that can be applied in the area of nutrition health economics, including decision trees and the Markov model (Nuijten 2015). Decision tree methods, as employed in this thesis, compares two or more health strategies by defining treatment pathways and assigning the associated health outcomes and resource use conditional on those care pathways. With decision analytic modelling, evidence (often from randomised controlled trials (RCTs)), is typically synthesised and extrapolated over time to estimate health effects and treatment needs for a jurisdiction of interest (JOI). That is evidence relevant to decision making in a jurisdiction which is usually beyond the scope of a single study follow-up period. Long-term effects and costs relevant to decision making for the relevant population can be robustly estimated with extrapolation methods. To estimate the clinical, economic and quality of life evidence for the effectiveness of any nutrition-related intervention will usually require observational studies for baseline risks, as well as appropriate application and extrapolation of relative treatment effects derived from RCTs. Markov models, structured around transition between health states and reflecting treatment pathways, can enable such extrapolation for given conditions with adaptation to allow for competing risks and impacts of ageing of populations, particularly with regard to higher risks of deaths with advancing age.

Nevertheless, research by Hawe and Ghali (2008), Shiell et al. (2008) and Eckermann et al. (2014, 2017) show that community network and multiplier impacts are key to assessing the long-term impact and success of health promotion and disease prevention strategies in complex community and aged care settings, such as those with community-based nutrition strategies for older adults. More generally, the success of community-based health programs depends on engaging with community networks and their ownership of programs, strategies or interventions, as well as consideration of community preferences, lifestyle, attitudes and behaviours. Building social capital enables the community to be involved and have ownership which then drives the long-term impact of a program beyond its evaluation period (Hawe and Ghali 2008, Shiell et al. 2008). Triangulated and combined assessment of individual short-term effects and community impacts enable the translation of the findings into sustainable strategies with long-term effects across communities. Where there may be community ownership and acceptance for the implementation of a health promotion program, community networks can help spread the scope and duration of programs and have multiplier impacts across networks in the wider community to the extent that the program continues to expand (Eckermann et al. 2014, Yeatman et al. 2014, Eckermann 2017).

2.2 Decision analytic modelling and cost-effectiveness analysis (CEA)

Decision analysis requires a robust and systematic approach for synthesising and translating data and for directly informing decision making, whether modelling expected effects and costs or their joint consideration under uncertainty (Briggs, O'Brien and Blackhouse 2002). Decision trees provide a systematic framework in which all of the available evidence can be appropriately synthesised and combined to inform robust decision-making applying decision analytic coverage and comparability principles (Eckermann 2017). Coverage in modelling requires consideration of the appropriate scope and duration of effects. Comparability principles ideally imply using RCT evidence to estimate treatment effects and consistently and jointly estimating incremental costs, effects and subsequent cost-effectiveness when translating evidence to a jurisdiction of interest (O'Brien 1996, Eckermann 2017, Eckermann et al. 2009, 2011). More generally, robust analysis allows for comparability, controls for risk factors, and considers modelling under uncertainty conditions. Hence, systematic and robust decision analytic models of incremental cost-effectiveness need to consider the principles of coverage and comparability of relevant evidence of incremental costs and effects for an unbiased estimation of the treatment effect on health outcomes and resource use (cost). Also, an appropriate comparator is needed and an adequate length of follow-up and scope of effects to cover expected incremental costs and health effects on the target population and setting. The focus is on a consistent and joint analysis of the incremental costs and health effects allowing for appropriate and robust synthesis and translation of evidence to the JOI in order to inform relevant decision making (O'Brien 1996, Eckermann 2017).

Decision tree models, both visually and explicitly, enable robust modelling of decision making across clinical, health system or, more generally, public policy (e.g. health and aged care system) allowing for cost and effects. That is the case whether comparing usual versus alternative treatment pathways, modelling alternative assumptions or population risk, extrapolating cost and effect evidence, or allowing for decision and parameter uncertainty (practice pathways, probabilities, payoffs or preferences). Decision analytic modelling allows the translation of evidence to the jurisdiction of interest (e.g. Australia) with different populations (change in baseline risk), practice (change structure of the tree) and prices and preferences (change payoffs in the tree) (Eckermann 2017). The decision tree model should be transparent so that one is able to describe the model, repeat the analysis and to generalise the findings to a wider population.

Trials and models are two approaches to economic evaluations, described by O'Brien (1996) as the "vampire of trials" and "Frankenstein's monster". RCTs allow an unbiased estimation of the treatment effect on health effects and resource use, while ensuring that the comparability principle is met, but the coverage often remains an issue (Eckermann 2017). That is, the estimated differences in health effect and resource use of the new treatment are specific to the trial conditions such as population risk, length of follow-up and other protocol conditions. Decision analytic modelling methods allow the synthesis of trial evidence through meta-analysis or indirect comparison, the translation (generalisation) of the trial evidence to other populations and settings by modifying the base risk and allows extrapolation over time (by using Markov models). Modelling enables the coverage principle to be met, but care is required to avoid inferential fallacies when synthesising and translating evidence from multiple sources and extrapolating beyond the original study follow-up (Eckermann 2017). A common inferential fallacy with cost minimisation is sequential partial hypothesis testing of cost or effect differences instead of cost-effectiveness estimation, such as on the basis of absence of evidence fallacies (Briggs and O'Brien 2001). There are fallacies in using relative risk with binary outcomes (e.g. mortality, survival) instead of odds ratio (OR) where the baseline risk differs, as may be the case in indirect comparisons across trials (Eckermann et al. 2009) and when translating evidence between trial and JOI (Eckermann et al. 2008, 2011).

The objectives of health economic analysis can be represented and encompassed by maximising the net benefit of joint research, reimbursement and regulatory decisions. In general, to maximise net benefit, trial evidence from the literature (i.e. individual RCTs and systematic reviews) are synthesised to estimate the relative treatment effect. The relative treatment effect is then modified by the target populations' baseline or epidemiological risk to get an estimate of each absolute effect difference. In particular, the treatment effect of the alternative strategy is applied to the target population (baseline risk). Absolute effect differences can be estimated to the size of benefits and harms covering the primary and secondary outcomes and also to the side-effects. Combining such benefits and harms with health related utility measures, the net clinical benefit (NCB, i.e. ΔE) and incremental net benefit (INB), i.e. value of incremental effect less incremental cost) can be estimated. INB extends NCB by valuing effects and including the associated incremental resource use and costs of the standard treatment relative to the new, alternative treatment or strategy.

Reimbursement decisions are made based on value for money, namely whether INB is positive given the incremental costs and value of incremental effects of a new treatment compared to the existing treatment. In particular, this thesis compares the incremental costs and effects of the Re-Engineered Discharge (RED) intervention to the natural history of older patient care in Australia. Summary measures for two strategy comparisons are best presented to inform decision making in the incremental cost-effectiveness plane (ICE plane), as INB curves and CEA curves. Historically, results have often been presented as incremental cost-effectiveness ratios (ICERs), which are the ratio of incremental costs relative to incremental effects, for a two strategy comparison.

$$\text{ICER} = (\text{Cost}_{\text{treatment}} - \text{Cost}_{\text{control}}) / (\text{Effect}_{\text{treatment}} - \text{Effect}_{\text{control}})$$

However, the ICER is unstable and does not have good statistical properties, particularly when evidence moves beyond the north-east quadrant of the ICE plane (Willan and Briggs 2006). However, the INB metric:

$\text{INB} = \lambda \times \Delta E - \Delta C$, where λ is the threshold value of the decision maker in the JOI;
is robust, well ordered and addressing the statistical problems of the ICER.

2.3 Hospital to health system impacts of malnutrition

Malnutrition has to be accepted as a major public health issue in Australian hospitals and appropriate funding allocated to address it. More dietetic services are needed in hospitals to meet nutrition needs, especially for ageing populations with high rates of malnutrition impacting on complexity of health and long-term care. The ratio of public-hospital dietitians to hospital beds was 1:60 in a NSW major regional referral centre in 2011 (Milosavljevic 2012). A similar dietitian to patient ratio might have applied to the study hospital of this thesis, where the 2009/10 data showed that dietitians were not always available to conduct nutritional assessments. Only 45% of older patients had a nutrition assessment by the dietitian within 72 hours of admission. From those patients not assessed within 72 hours, 25% had no assessment at all (chapter 4, section 4.2.1, Fig. 4.3).

It is difficult to evaluate and compare the various malnutrition prevalence rates of older patients and associated clinical outcomes among studies or even countries. These depend and can vary with population characteristics, geographical location, health care setting, the timing of screening and assessment and the different nutritional diagnostic criteria and lengths of follow-up periods. Several malnutrition prevalence studies have been undertaken in public (teaching) and private acute care facilities in Australia in the last eighteen years showing that hospital malnutrition has been an ongoing problem (Middleton et al. 2001, Lazarus and Hamlyn 2005, Banks et al. 2007, Thomas et al. 2007, Adams et al. 2008, Gout et al. 2009, Bauer et al. 2011, Mudge et al. 2011, Charlton et al. 2013, Dent et al. 2017, Morris et al. 2018, Young et al. 2018) and as part of the Australasian Nutrition Care Day Survey (ANCDS), the first multicenter study across Australia and New Zealand (Agarwal et al. 2012b), see Table 2.1. These studies report on associations between malnutrition and hospital length of stay, patient-related malnutrition risk factors, dietetic referrals, malnutrition documentation and mortality, in older patients, and even financial losses to hospitals. Malnutrition has been identified in these studies using either the Subjective Global Assessment, the MNA or the Malnutrition Screening Tool (MST). It has been reported that patients with malnutrition (prevalence ranging from 23-53%) stayed significantly longer in hospital compared to well-nourished patients, ranging from 4.5 days (Thomas et al. 2007) to an additional 4.5 days (Gout et al. 2009), 6 days (Middleton et al. 2001) or 11.4 days over a 12-month follow-up period (Charlton et al. 2013). However, despite the high rate of malnutrition identified, only 36% of these malnourished/at risk patients were referred to a dietitian during their hospital stay, and only 29% of cases had been documented as

Table 2.1 Malnutrition prevalence studies undertaken in acute care (public and private) facilities in Australia

Author, Year	Aim	Study design & setting	Nutrition screening tool	Participants (age, gender)	Key findings
Middleton et al. (2001)	To determine: (i) malnutrition prevalence, (ii) effect of malnutrition on 12-month mortality , (iii) proportion of patients previously identified to be at nutritional risk	Prospective study, two public teaching hospitals	Subjective Global Assessment	819 inpatients, median age 65 years, 56% male, 44% female	36% malnourished overall, 29.7% 12-months mortality rate in malnourished vs. 10.1% in well-nourished, longer median length of stay (LOS) for malnourished (17 days) vs. well-nourished (11 days), 36% malnourished previously identified as at nutritional risk
Lazarus & Hamlyn (2005)	To determine: (i) malnutrition prevalence, (ii) whether malnourished were identified and documented as malnourished, (iii) impact of poor documentation on financial hospital reimbursement	Case study, private hospital	Subjective Global Assessment	324 inpatients, mean age 65+ years, 52% male, 48% female	42.3% malnourished, 1 of 137 malnourished documented as malnourished, 15% malnourished referred to dietitian; $125,311 shortfall in hospital reimbursements
Banks et al. (2007)	To determine: (i) malnutrition prevalence in public acute & residential aged care facilities, (ii) effects of variables associated with malnutrition in these populations	Multicentre, cross-sectional single-day nutritional status audits, 20 public acute hospitals & 6 residential aged care facilities	Subjective Global Assessment	2208 acute & 839 aged care subjects, mean age 65+ years, 52% male & 47% female (acute care), 36% male & 63% female (aged care)	34.7 ± 4.0% & 31.4 ± 9.5% malnourished (acute care), 50.0% & 49.2% (aged care) in audits 1 & 2; variables associated with malnutrition: older age groups, male (in aged care), metropolitan facility location & medical specialty
Thomas et al. (2007)	To determine: (i) nutritional status of patients admitted to Acute Assessment Unit, (ii)	Prospective, observational study, acute assessment unit	Scored Patient Generated-Subjective Global	64 patients, mean age 79.9 ± 11 years, 76% female	53% malnourished; weak correlation between LOS & PG-SGA score, overall short LOS at median of 4.5 days

	association between nutritional status & LOS		Assessment (PG-SGA)		
Adams et al. (2008)	To determine: (i) malnutrition prevalence in population of elderly hospitalised patients, (ii) health professionals' perceptions & awareness of signs & risks of malnutrition & treatment options available	Quantitative & qualitative study, major tertiary teaching hospital	Mini Nutritional Assessment, researcher-designed questionnaire	100 elderly patients, 70+ years, 50% male & female	30% malnourished, 61% at risk of malnutrition; 7-9% malnourished referred to dietitian; good knowledge of medical risk factors for malnutrition but poor of malnutrition risk factors (recent loss of weight & appetite)
Gout et al. (2009)	To determine: (i) malnutrition prevalence, diagnosis, documentation and referral rates among hospitalised patients, (ii) potential shortfalls in financial hospital reimbursement as result of malnutrition misdiagnosis.	Retrospective audit of malnourished patients' medical histories, acute care wards of large metropolitan tertiary teaching hospital	Subjective Global Assessment	275 randomly selected inpatients, 59.5 ± 19.9 years, 52% male, 48% female	23% malnourished; longer LOS for malnourished by 4.5 days vs. well-nourished; 36% malnourished/at risk referred to dietitian, 29% documented as malnourished by dietitian; financial shortfall of AU$27,617 in hospital reimbursements
Bauer et al. (2011)	To determine: (i) malnutrition prevalence, (ii) associated factors including meal consumption in Australian hospital	Cross-sectional study, private acute care hospital	Subjective global assessment	147 inpatients surveyed across five wards, mean age: 65.6 ± 15 years, 32% male, 64.6% female	19.7% malnourished (17.7% mild to moderate, 2% severe); factors associated with malnutrition: underweight, unintentional weight loss, eating less than normal during past week, eating half or less of meal on average during survey day
Mudge et al. (2011)	To determine: (i) proportion of older medical patients with inadequate nutritional intake, (ii) patient-related factors associated with outcome	Prospective cohort study (part of larger multi-methods study), large metropolitan public teaching hospital	Mini Nutritional Assessment	134 inpatients, mean age: 80 years, 51% female	31% malnourished, 38% at risk of malnutrition, 31% well-nourished; patient-related factors: poor appetite, higher BMI, cancer diagnosis, delirium, feeding assistance

Agarwal et al. (2012b)	To determine: (i) nutritional status, (ii) dietary intake of acute care hospital patients	Australasian Nutrition Care Day Survey (ANCDS) as multisite cross-sectional study, 56 acute care hospitals across Australia & New Zealand	Subjective Global Assessment	3122 patients, mean age: 64.6 ± 18 years, 53% male, 47% female	32% malnourished overall, 41% at risk of malnutrition; 55% malnourished & 35% well-nourished consumed ≤50% of food during 24-h audit
Charlton et al. (2013)	To determine: (i) whether nutritional status at hospital admission predicted clinical outcomes at 12 months follow-up	Secondary data analysis, acute tertiary hospital	Mini Nutritional Assessment	774 patients, mean age: 83.5 ± 18 years, 37.7% male, 62.3% female	34% malnourished, 55% at risk of malnutrition; at risk patients 2.46 times & malnourished 3.57 times higher risk of poor clinical outcome (mortality/discharge to higher level of care); 11.4 days longer LOS for malnourished vs. well-nourished; 14% 12-months in-hospital mortality
Dent et al. (2017)	To determine: how well the Mini Nutritional Assessment Short Form performed as nutritional screening tool when calf circumference replaced body mass index as anthropometric measurement	Comparative study, Geriatric Evaluation and Management Unit	Mini Nutritional Assessment & its short-forms	100 patients, mean age: 85.2 ± 6.1 years, 75% female	40% malnourished, Mini Nutritional Assessment correlated highly with both of its short-forms (for body mass index & calf circumference versions)
Morris et al. (2018)	To determine: health outcomes among Indigenous & non-Indigenous patients	Prospective cohort study, three regional hospitals	Subjective Global Assessment	608 medical inpatients, median age: 61.6 years, 48.4% female	41.1% malnourished; Indigenous more likely to be malnourished than non-Indigenous (Odds Ratio 1.45); malnourished Indigenous more likely to be readmitted within 30 days (Relative Risk (RR) 1.53) & six

					months (*RR* 1.40) & less likely to be alive at 6 months (*RR* 1.63) than non-Indigenous, malnutrition associated with increased healthcare utilisation & decreased survival
Young et al. 2018	To determine: nutritional intake of older medical inpatients as dietary & mealtime interventions were progressively implemented into routine practise	Series of three prospective cohort studies, public metropolitan teaching hospital	Malnutrition Screening Tool	320 inpatients, 65 + years, admitted in three 5-month periods: cohort 1 (2007-2008); cohort 2 (2009) & cohort 3 (2013–14), about 45% male across cohorts	49% at risk of malnutrition; significant & progressive improvements in energy & protein intake between cohorts through fortified meals & mid-meals with mealtime assistance

malnourished in the medical history by the dietitian (Gout et al. 2009). In other hospitals, only 15% (Lazarus and Hamlyn 2005) and 7-9% (Adams et al. 2008) of malnourished patients were referred to a dietitian. Malnourished patients had a higher mortality rate of 30% compared to well-nourished of 10% over a 12-month follow-up (Middleton et al. 2001), while a 14% prevalence of in-hospital mortality was found in older acute care patients with malnutrition within a 12-month follow-up (Charlton et al. 2013). Common variables associated with malnutrition included recent unintentional loss of weight and appetite (Adams et al. 2008, Bauer et al. 2011, Mudge et al. 2011), but also older age, being male (in aged care), metropolitan facility location, medical specialty (Banks et al. 2007), underweight (Bauer et al. 2011) and higher BMI, cancer diagnosis, delirium, feeding assistance (Mudge et al. 2011).

In addition, hospital malnutrition is associated with higher morbidity and readmission rates, surgical complications and delayed recovery/discharge, decreased quality of life and associated increased need for health care (Stratton et al. 2003, Kagansky et al. 2005, Brantervik et al. 2005). These issues are, in turn, associated with higher hospital costs of subsequent patient treatment, secondary to the management of the primary medical condition for which they had been admitted (Barker et al. 2011). Hospitals administratively, and the health system in practice, over time experience financial losses due to unrecognised and undocumented malnutrition in hospitals under case-mix-based funding in Australia as well as in New Zealand (Agarwal et al. 2015), but also in other countries including Germany (i.e. EUR 35,280 per patient year or EUR 360 per malnourished patient, 8.3% of the total reimbursement for all patients of EUR 423,186) (Ockenga et al. 2005). Some Australian studies have estimated unclaimed reimbursements from patient admissions where malnutrition was not recorded as a comorbidity or complication of the admitting disease DRG (Ferguson et al. 1997, Lazarrus and Hamlyn 2005, Gout et al. 2009, Agarwal et al. 2015). Estimated annual financial losses related to hospital reimbursement because of coding omissions for malnutrition range from AUD 125,311 to AUD 1,850,540 per hospital were reported.

Since the changes to the criteria for malnutrition diagnosis in 2008, medical coders in acute hospitals assign a DRG according to the underlying diagnosis, surgery, presence of comorbidities, complications or other interventions and can, if adequately documented by a dietitian in the medical record, also assign a code for malnutrition as a co-morbidity using the DRG system, e.g. introducing the concept of a malnutrition sticker (DAA, 2009, Walton 2009).

Australian hospitals are subsequently reimbursed for patient admissions based on DRG classifications. Malnutrition coding can potentially move the DRG to a 'higher' classification or increase the case complexity and thereby attract higher hospital reimbursements for that patient. There are differences in nutritional status between DRG's, hence the specific groups, likely to require nutrition intervention, should be identified so that resources can be directed to patient groups of greatest need. However, malnutrition coding should not mainly be done to attract case-mix-based funding, rather it is the implementation of nutritional interventions at the right time following due process that should drive the coding. A standard process of malnutrition identification and documentation by dietitians is required in collaboration with medical coders for correct malnutrition coding in hospital patients to improve nutritional support and obtain appropriate hospital reimbursements (Agarwal et al. 2015). This highlights dietetics as an important part of a comprehensive medical treatment. The malnutrition associated hospital reimbursements improve the dietitian's profile among other hospital staff and can finance costs of additional dietetic staffing within the hospital to continue to identify and treat malnourished patients (Cobb et al. 2011, SVHA 2017).

It has been reported that even by following the standard procedures for managing malnutrition after acute hip fracture, which includes protected meal times, nutrition screening on admission, dedicated dietitians in each ward and high quality food services, the majority of the older female patients consumed only half of their energy and protein requirements (Bell et al. 2013). In a follow-up prospective before and after comparative intervention study, the same authors showed that multidisciplinary and multi-modal nutritional care improved nutritional intake and outcomes in this older inpatient population (Bell et al. 2014). The outcomes included more discharge back to the community, rather than high level needs or aged care settings, and lowered inpatient mortality in the acute hip fracture patients. These Australian studies concluded that a strategy that considered malnutrition as a priority condition, accompanied by promotion of nutrition as medicine within a coordinated multidisciplinary nutritional care approach, enhanced foodservices and by improving patient knowledge and awareness of nutrition and greater encouragement of patients to eat, were more successful in improving the dietary intake of acute hip fracture inpatients during their hospital stay compared to individualised nutritional care (i.e. routine nutritional screening and assessment on admission, high protein/energy diets and implementation of individualised intensive dietitian delivered therapy for all nutritionally at risk or malnourished patients).

The use of nutritional support such as oral nutrition supplements, enteral tube feeding via nasogastric, naso-enteral and percutaneous tubes, and parenteral nutrition are effective and a valuable integral part of medical therapy, disease management and prevention for any patient malnourished or at risk of malnutrition (Nuijten 2015). The use of oral nutritional supplements has been shown to improve weight, protein, nutrient and energy intake, nutritional status, physical function, quality of life and length of stay in acute care (Milne et al. 2009). However, oral nutritional supplements should be used in conjunction with other strategies to increase oral intake. The first step to increase oral intake should always be the use of real foods as part of small, frequent, nutrient dense meals (Schneyder 2014). Only if the patient rejects any food and/or oral nutritional supplements, should enteral or parenteral nutrition be considered by the dietitian under clinical guidance. The review by Seres et al. (2013) supports the use of enteral nutrition in patients requiring nutritional support, over parenteral nutrition, because enteral nutrition leads to fewer infectious complications, earlier restoration of gut function, reduced length of hospital stay and reduced overall hospital costs.

Only a few systematic reviews and meta-analyses have started to investigate nutritional support from a health economics perspective, and these reports suggest that any such support is incrementally cost-effective (Pritchard et al. 2006, Walzer et al. 2014, Mitchell and Porter 2016). However, a recent review by Elia et al. (2016) noted that the effects of different types of nutritional interventions in various settings have often not been separated. That review focused on the cost and cost-effectiveness of using standard oral nutritional supplements in the hospital setting and found that, standard oral nutritional supplements are effective within admission (i.e. reduced mortality, complications and length of hospital stay) and cost-effective (avoided pressure ulcer development and release of hospital beds and gain of quality adjusted life years), indeed cost saving and hence dominating standard care. Nuijten (2015) described a systematic review by Freijer et al. (2014) of studies managing various patient populations with or at risk of disease-related malnutrition from a health economics perspective, with oral nutritional supplements as the most studied form. Using a linear decision analytical model, cost and benefits were assessed comparing the use of oral nutritional supplements versus no use of oral nutritional supplements in a virtual population of abdominal surgery patients (Freijer and Nuijten 2010). The Dutch health economic study showed that the use of oral nutritional supplements led to a 7.6% cost saving per patient, reduced hospitalisation cost by 8.3% and was associated with a 0.72-day reduction in the average LOS. These beneficial outcomes led to a minimum annual cost saving at a population level of EUR 40.4 million (Freijer and Nuijten 2010). In Germany, a similar study that assessed the health economic impact of oral nutritional supplements in the community setting resulted in cost savings and better clinical outcomes due to reduced hospitalizations (Nuijten and Mittendorf 2012). The additional costs for oral nutritional supplements (EUR 534) were off-set by reduced hospitalization costs (EUR 768), resulting in an overall cost saving of EUR 234 per patient.

While most studies have focused on a treatment model for managing malnutrition in the hospital, Lim et al. (2013) provided a more comprehensive model that ranged from nutrition screening at hospital admission to referral for nutrition assessment and inpatient nutrition intervention through to dietetic outpatient clinic follow-up appointments post-discharge. The pre-post study evaluated an ambulatory nutrition support service (i.e. four months of post-discharge care with telephone calls, outpatient appointments and home visits for patients missing their appointments) for malnourished patients post hospital discharge, with regard to follow-up rate, nutritional status and quality of life. In the baseline survey conducted in 2008, it was found that only 15% of adult inpatients (n = 261) returned for a dietetic follow-up consultation within four months post-discharge. After implementation of the ambulatory nutrition support in 2010, a 100% follow-up rate (n = 163) was achieved as well as demonstrated improvements in nutritional status and quality of life (Lim et al. 2013).

Multiple studies have documented that hospital malnutrition is a highly significant independent clinical risk factor and/or a highly relevant clinical cost factor (Loeser 2001, Correia and Waitzberg 2003, Russell 2007, Stratton and Elia 2007, Norman et al. 2008, Lim et al. 2012, 2014). However, these studies mainly focused on the health effects/clinical events (e.g. increased length of hospital stay) associated with malnutrition and resulting costs to health care facilities separately. Few health economics studies, with the exception of Graves et al. (2009), have considered the joint incremental health effects, costs and cost-effectiveness or net benefit of their nutrition-related intervention or care strategy conditional on the decision maker's threshold values of effects in the JOI. Graves' modelling study estimated the cost-effectiveness of a comprehensive nursing and physiotherapy intervention with a 24-week follow-up period to reduce hospital readmissions among older patients. They used data from a randomised controlled trial with acute care patients aged 65 years and older of an Australian tertiary metropolitan hospital. The model showed that this intervention was not only cost saving (AUD 333) but also improved health outcomes (extra 0.118 quality adjusted life years) and had a net monetary benefit of almost AUD 8,000 per individual offered the intervention compared to usual care for the 24-week follow-up.

The current research study not only shows the effect of malnutrition on health outcomes, costs and cost-effectiveness combined, but also moves beyond within setting index hospital admission impacts of malnutrition to consider health system impacts for optimised health care. That is, instead of focusing on the potential for better dietary management to reduce within hospital cost, consideration is given to optimising health system care and management of malnutrition. Since malnourished patients have higher risks of adverse clinical outcomes (Charlton et al. 2013), the impacts on the health care system are seen downstream as these patients subsequently require greater nursing care, more medications, experience more rehospitalisations associated with prolonged length of stay, and an increased risk of overall mortality and reduced quality of life (Middleton et al. 2001, Correia and Waitzberg 2003, Pirlich et al. 2006). In evaluating program interventions and policies and efficiency of performance of hospital providers in practice, Eckermann (2004) and Eckermann and Coelli (2013) point to the necessity of allowing for health system downstream health effects and cost impacts. They argue that this is required in order to optimise care and avoid perverse incentives for cost-shifting (i.e. increased need for health care post-discharge) and outcome-shifting (i.e. expected negative effects on health outcomes beyond discharge).

2.4 Current in-hospital and post-hospital care of malnourished older patients

It is apparent when researching the relationship between malnutrition and the consequences for patients and the health care system that benefits to individuals, hospitals and the wider health and social systems exist if malnutrition is correctly identified and treated. Therefore, nutrition screening, monitoring and reporting/documenting is suggested to be crucial for improving patient health outcomes and lowering health system costs in the acute hospital setting. The current state of knowledge is that an all-of-hospital approach to nutritional care is required to identify and treat malnutrition. Loeser and his colleagues have put this into clinical practice with the “Kassel Model” experience (Loeser 2011). This clinically evaluated and established model involves a multidisciplinary nutrition team of doctors, nurses, nutritionists, dietitians, medical coders, hospital management and allied health professionals. In order to prevent or reverse the decline in general health for malnourished hospitalised patients, early screening and assessment on admission and clinical treatment pathways with appropriate dietary support (i.e. specific menus and nutrient and energy-enriched snacks between meals, also medical nutrition for malnourished patients) is necessary to optimise the patient‘s chances of attenuating some or all of the negative clinical outcomes related to malnutrition. Routine malnutrition screening using one of the validated nutrition screening tools provides the basis for nutrition and dietetic intervention and for prescription referrals of appropriate nutritional support. Since malnutrition is mostly recognised in patients with a poor health status treated for the disease being admitted, it still makes it difficult to study the effects of nutrition interventions (Philipson 2016).

Nutrition risk or malnutrition screening, performed by nursing or nutrition assistant staff, but able to be completed by any trained health professional, usually consists of two or three simple questions validated to predict malnutrition risk. Patients identified through malnutrition screening as ‘at risk‘ are subsequently referred for an in-depth nutritional assessment (Barker et al. 2011). The nutrition assessment is a diagnostic and more comprehensive tool to determine the nutritional and physical status using the patients’ medical, nutritional and medication history, anthropometric and laboratory data (Association A.D. 1994). It requires greater skill and time than the nutrition risk screening and is usually performed by a dietitian (Barker et al. 2011).

Walton (2009) highlighted that dietitians are in a good position to endorse the ‘Evidence-based practice guidelines for nutritional management of malnutrition in adult patients across the continuum of care’ released by the DAA in 2009 (Watterson et al. 2009). These guidelines emphasise patient-centered care protocols for malnutrition diagnosis, adequate provision of food (e.g. nourishing snacks, food fortification) and protected mealtime environment as well as feeding assistance. Dietitians are further identified as nutrition experts addressing malnutrition and staff education on identification, documentation and treatment of malnutrition. Data from the Australasian Nutrition Care Day Survey (ANCDS) in 2010, a multicenter study, showed a poor adherence of the 370 participating acute care hospital wards across Australia and New Zealand to the evidence-based nutrition care practices related to nutrition screening, nutrition intervention and choice of the screening tool (Agarwal et al. 2012a). About 64% of the wards conducted nutrition risk screening, 14% of the wards conducted nutrition risk rescreening, 78% of the wards referred patients to dietitians and commenced a nutrition intervention protocol. About 90% of the wards provided feeding assistance and only 5% of the wards implemented protected meal times. A later study determining current strategies of dietitians to assess, treat and monitor older patients diagnosed with malnutrition or increased risk of malnutrition in Australia showed that dietitians usually adhere to the current evidence-based assessment and treatment practice guidelines using validated assessment tools (Demeny et al. 2015). Based on Demeny's online survey informed by the DAA's evidence-based practice guidelines, 59% of the participating dietitians working with older adults (65+) used a validated assessment tool. Also 95% of the dietitians prescribed oral nutritional support for malnourished or nutritionally at risk patients and 36% of dietitians considered an increase in energy and protein intake. Nevertheless, 14% of dietitians worked in services with no malnutrition policies and treatment protocols in place. These studies indicate that specific and common guidelines to assess and manage malnutrition in older patients are required to be used in all hospital service settings as part of hospital performance quality of care.

Research from different healthcare sectors in the Netherlands show that the prevalence of malnutrition in hospitals slightly decreased when there was an increased focus on regular malnutrition screening and treatment of new patients as part of their hospital performance (Health Council of the Netherlands 2011). Since disease-related malnutrition in older persons often begins at home, early recognition and treatment of malnutrition is crucial to avoid further malnutrition and accelerate recovery. Malnutrition left untreated worsens after hospital admission and in the convalescence period after hospital discharge. The guidelines of the Dutch Malnutrition Steering Group (Fight Malnutrition 2012) suggested routine nutrition screening performed by home carers or within the general practice setting, as did an Australian study by Hamirudin et al. (2014).

More focused nutritional management has the potential to improve care, quality of life of the older adults and prevent hospital and downstream costs. Due to the complex causes of malnutrition resulting from socio-economic as well as medical determinants, solutions need to be multifaceted. Although cost-effectiveness data from well-conducted nutrition economic studies could aid in the process of decision making and allocation of limited healthcare funding, health economic assessments for nutrition support and nutritional interventions are currently limited. Freijer et al. (2015) concluded that quality methods need to be developed for this new field of nutrition outcomes research to evaluate clinical, economic and quality of life outcomes of nutrition support on patient health for societal health care decision making. Further, if nutrition care services were better coordinated in hospital and extended into the community then the needs for aged care services following hospital discharge could be significantly reduced.

2.5 Issues with hospital discharge and aged care

The Australian health care system has placed pressure on acute care facilities to reduce hospital length of stay in the face of the increasingly aging Australian population and decreased acute bed availability (Bauer et al. 2009). In 2010, people aged 65 and older made up 13.5% of Australia's population and was projected to increase to 22% in 2056 (Australian Bureau of Statistics 2013).

Many older Australians prefer to live in their own homes, e.g. 95% lived in households and the remainder in residential aged care facilities in 2015 (ABS 2016). This is in line with the government’s strategy to keep them healthy at home for longer (Productivity Commission 2011). Therefore, community-based aged care programs aim to enable more older Australians to remain living in their community (AIHW 2017). In addition, the demand for aged care services is driven by the population aged 70 and older that is expected to grow between 89.0% and 98.8% by 2036. Adults aged 85-89 are projected to be the fastest growing age bracket with 105,000 older adults that need aged care in Australia by 2036, followed by the 90-94 and 80-84 age group with 90,000 and 70,000 older adults, respectively (Core Data, 2017).

About 55,000 hospital bed days were occupied by long-stay older patients in NSW at the 2012-13 census while waiting for beds in overstretched nursing homes, putting more strain on the public health system. "Bed blocking" has always been an issue in Australia. Because of the high cost to care for a patient in hospital, which is about six times more expensive (AUD

1,200 per day for the average NSW bed) than in aged care (AUD 200 for high-needs aged care beds), Australian health and aged care providers have suggested that the government should fund rehabilitation programs in the community under Medicare in a short-term stay environment. Alternatively, funds could be redirected to enable older adults to remain in their own homes, instead of requiring placements in aged care facilities. Being in their own homes could also motivate and empower older people properly educated about their malnutrition condition at hospital discharge to improve their care ability and health status to avoid expensive aged care facilities. In 2014–15, the Australian government spent about AUD 16 billion on aged care services; AUD 1.3 billion on home care, AUD 10.8 billion on residential aged care and the remaining AUD 3.9 billion on other aged care. In Australia in 2015-16, about 728,900 older adults accessed community-based aged care programs (Commonwealth Home Support Program and Home Care Packages Program), whereas 291,900 older adults were admitted into residential aged care splitting into permanent (235,000) and respite (56,900) care and 24,700 older Australians accessed transition care (AIHW 2017c).

Older adults usually enter the aged care system through home care before eventually entering the more individualised but permanent residential aged care. Since 2015, the Commonwealth Home Support Programme (basic support services for living at home independently) and the Home Care Packages Program (complex, coordinated and individualised care at a low, intermediate and high care level) have been available for older Australians. Respite care is a temporary, short-term care option offered either at a low or high care level within a residential aged care facility. This is considered an intermediate step to entry into permanent residential aged care and is helpful for supporting those older persons who want to live at home for as long as possible (AIHW 2017b).

There is growing momentum in Australia for 'nurse navigators' to work on the holistic care of individuals, coordinate care across hospital silos and promote self-management of chronic diseases (Hudson et al. 2018). These nurses target patients who are frequent users of hospital services with a view to alleviate preventable readmissions. The review by Manderson et al. (2012) provides some evidence that integrated and coordinated care by a nurse navigator can benefit older adults with complex chronic conditions that transition across multiple healthcare settings and are at high risk to receive fragmented care. Conway et al. (2017) have also reviewed the evidence of the benefits of nurse care coordinator roles. The evidence suggested positive patient and health service outcomes through ongoing patient interaction and follow-up of the disease status, transition care and the use of behaviour change principles.

While debate about reducing waiting lists, for example elective surgery, is important, costs to the health system for unplanned preventable readmissions is ignored. Service cost reductions and rationalisation, especially for government hospitals, result in frail older patients being discharged as early as possible, and consequently being in a sicker and more dependent state (Bauer et al. 2009). This particularly becomes problematic when there is poor support for the patient at home after discharge and leads to higher readmission rates and cost. Where patients' malnutrition fails to improve during hospitalisation and/or fails to be addressed at separation, disease-related malnutrition becomes more prevalent in the post-discharge setting. Therefore, the focus is more and more shifting to the quality and cost impacts associated with post hospital discharge, most obviously linking acute hospital care with primary or community health care. Importantly, such linkages need to consider health and aged care system cost-effectiveness, especially when considering dependent older patients with malnutrition.

2.6 Continuity of care from hospital admission to post-discharge

There is a lack of robust research on the effectiveness and cost-effectiveness of integrated care initiatives. Evidence of outcomes in patient populations with complex comorbidities such as the frail older adults, compared to heart failure or mentally ill patients for example, is not consistent (McDonald et al. 2007). More generally, it is difficult to compare different strategies between acute and primary care settings.

Bywood et al. (2011), in reviewing the literature, found that direct communication between health service providers and patients was the most commonly used strategy to improve patient health outcomes in aged and mental health care. Improvement in patient health outcomes was achieved by establishing multidisciplinary teams in chronic disease management, coordinating access to primary care providers (PCPs) and allied health services for complex care patients, strengthening the relationship between service providers (also through co-location of primary health carer and other health services) to support coordination of care, as well as developing tools (e.g. common assessments, care plans, decision support) and systems for communication and information sharing that can be used across services. However, the financial constraints of community health service providers often limit the extent of their collaboration with other health care sectors.

Older malnourished patients require complex care related to their medical, cognitive, functional as well as social needs after discharge. Thus, an effective discharge planning process and a comprehensive discharge plan (discharge summary) are needed to identify individual patient needs to maintain or improve their health outcomes after hospital discharge. Research reviewed by Bauer et al. (2009) identified a direct correlation between the quality of discharge planning and hospital readmission. Discharge planning is a complex process of assessing and preparing for the complex patient's care needs, development of a comprehensive plan, educating the patient and caregivers as well as providing follow-up care to achieve positive health outcomes. Effective discharge planning can reduce unplanned readmissions and minimise the potential for prolonged hospitalisation, as well as post-discharge complications (ranging from anxiety through to mortality), and can also increase the patient's satisfaction with the health system (Bauer et al. 2009).

Further, the review by Bauer et al. (2009) in relation to hospital discharge practices for frail older adults and their family highlights important factors for quality discharge planning. Alongside multidisciplinary teams improving patient in-hospital health outcomes, multidisciplinary collaboration among health professionals, patients and their families or caregivers is also required for effective discharge planning. Discharge coordinators promote effective communication between staff members and patients and their caregivers. Early assessment and discharge planning soon after the patient's admission are also expected to increase the effectiveness of the discharge planning process (Naylor et al. 1999).

Given the short hospitalisation period and subsequent reduced recovery time for often quite dependent patients, hospitalisation of older patients can leave less time to adequately evaluate the patients' care needs and to establish a comprehensive discharge plan. Naylor's study (1999) also found that the commitment and on-going involvement of families and caregivers, accompanied by reassessment throughout the hospital stay, as well as follow-up support after discharge, leads to positive outcomes more often for ill older adults and their families, compared to early commencement of discharge planning alone (Rosswurm &

Lanham 1998). Other factors promoting successful discharge planning for older patients include appropriate guidelines for access to health services and community resources such as support groups, counselling after discharge and adequate documentation of the patient's history on admission (Naylor et al. 1999, Bauer et al. 2009).

Various discharge models have been established to improve in-patient management and health outcomes of hospitalised frail older adults, including discharge planning and discharge support arrangements, comprehensive assessments (e.g. aged care assessment) and geriatric management units (Shepperd et al. 2004). Reviews on the effectiveness of these discharge models have shown lower hospital readmission rates for older patients receiving hospital and home follow-up care (Parker et al. 2002) and for older patients with congestive heart failure (Phillips et al. 2004, Naylor et al. 2004). Other systematic reviews have not reported sufficient benefits associated with discharge planning (Shepperd et al. 2004) and telephonic follow-up (Mistiaen and Poot 2006) in reducing hospital readmissions. Nevertheless, home care companies that use personal care navigators and nurse care managers have shown a reduction in unplanned hospital readmission rates and net cost savings. These approaches educate and support the patient with the correct medication administration, encourage attendance at follow-up appointments and implement a long-term health plan through their weekly home visits after discharge (Sahli 2015).

An Australian study showed that an intervention to provide acute patients aged 65 years and older with a comprehensive nursing and physiotherapy assessment and individualised program of exercise strategies that commenced during hospital admission, together with a nurse conducted home visit with telephonic follow-up, reduced hospital readmissions by half (Courtney et al. 2009). This exercise-based intervention commencing in hospital and for 24 weeks after hospital discharge improved the quality of life for older patients at risk of hospital readmission and proved to be cost-saving. Compared to usual care over a 24-week period, net cost savings were estimated a AUD 333 per patient (95% Bayesian credible interval AUD -1,932:1,282), whith an estimated 0.118 additional quality adjusted life years (95% Bayesian credible interval 0.1:0.136). The incremental net benefit per individual was consequently estimated as AUD 7,907 per patient (95% Bayesian credible interval AUD 5,959: AUD 9,995) for a threshold value of AUD 64,000 per QALY in the Australian setting (Graves et al. 2009), but would remain positive and greater than $333 per patient for any positive value per QALY.

Hospital readmissions and emergency department (ED) visits after hospital discharge have been a reoccurring problem for health systems worldwide, particularly for countries such as the United States where non-standardised hospital discharge and transition procedures exist (Jack et al. 2008, Markley et al. 2013). In the United States, about 18% of Medicare patients (over 65 years) are readmitted to the hospital within 30 days of discharge at a cost of USD 15 billion (Medpac 2007). Effective discharge planning has become a priority in the US and is included as an indicator of the quality of hospital care (Birmingham 2004). The Medicare Payment Advisory Commission (MedPAC) in the US introduced penalties (receiving lower per case reimbursements) for excessive readmission rates (Meyer 2011). A study by the Royal Australasian College of Physicians in 2013 reported that 'unplanned readmissions' that affect up to 25% of acute hospitalisations of older patients could be prevented. The cost of preventable hospital readmissions were subsequently estimated at close to AUD 1.5 billion annually across Australia. In interpreting these findings, Brankin (2014) indicates that such readmission rates in Australia should be seen as key hospital performance quality of care indicators rather than just a monitor of system activity. That is, considered to be endogenous rather than exogenous activities (Eckermann and Coelli 2013; Eckermann 2017). According to the Australian Commission on Safety and Quality in Health Care, more research on hospital readmission rates are needed in Australia (Swannell 2013).

It seems obvious that unplanned or preventable readmission arise from suboptimal processes and clinical errors in the health care system, including premature discharge home, inappropriate post-discharge support, insufficient follow-up, therapeutic errors and medication-related adverse events, poor hand-over procedures from hospital to PCPs, or complications following medical procedures or obtained during a hospital stay, such as pressure ulcers and hospital-acquired infections (Sahli 2015, Alper et al. 2016). Readmissions can also reflect patient barriers to appropriate integration of health system care such as the disconnection between hospital and community-based care and fragmentation of care at discharge. Adding to these problems is the difficulty for PCPs to adequately care for patients following their complex hospitalisations, because of incomplete discharge documentation (Kripalani et al. 2007). Therefore, a complete, accurate and timely patient discharge summary is essential for effective communication between inpatient and outpatient health care providers in order to reduce potential adverse events and hospital readmissions (Kaur et al.

2009). Barriers from a lack of communication and coordination at transition from hospital to community care, in particular, leave older patients underprepared regarding the self-administration and supply of their medication. The navigation of post-discharge support is often accompanied with a lack of patient cognitive ability and limited health literacy. Incorrect use or discontinued use of medication and not attending follow-up appointments with the primary care physician are the major risk factors increasing readmissions for older Australians, similar to the American setting (Sahli 2015, Alper et al. 2016). While older Australians with complex comorbidities will always have higher risk for readmission, at least the major risk factors, i.e. poor medication management and missing follow-up appointments, can be reduced significantly.

The need for the RED care model as alternative hospital care and discharge strategy

In addressing care needs, the literature review highlighted evidence of a care model, linking hospital medical care with community health and other care such as aged care, called 'RED (Re-Engineered Discharge)' developed by Jack and colleagues at the Boston Medical Centre, Massachusetts (Jack et al. 2008). The RED care model focusses on in-hospital education of the patient and their carers for self-management through the nurses' teach-back strategy, comprehensive in and after hospital care planning and post-discharge telephone follow-up call two to three days after discharge to reinforce the discharge plan as well as engaging with post–acute care providers in the community. There is also in-service education of hospital staff about RED and the care transition, health literacy and patient safety to both educate and support system wide understanding and ownership. The discharge nurse advocate plays a central role in RED by improving communication and systematic coordination of care services. The advocate creates the discharge summary, including the contact information of the PCP, dates for follow-up appointments and tests, a color-coded medication plan and emergency instructions. The patients and the PCP receive a copy of the discharge summary at hospital separation. After developing the tools of the RED care model, the principles and components of RED were adopted and recognized by the National Quality Forum as one of their "Safe Practice" on the hospital discharge (Jack et al. 2008).

Jack and colleagues completed a randomised, controlled trial at the Boston Medical Centre in Massachusetts, United States, comparing the effect of RED on hospital utilisation after discharge with usual care receiving standard discharge (Jack et al. 2009). The RED intervention group showed a 30% reduction in hospital utilisation (readmissions and ED visits combined) within the critical first 30 days of index discharge and reduced the total cost by 34% (combining the actual cost of hospital and ED visits), compared to usual care. The reduction in total cost (including hospital utilisation and estimated primary care outpatient visits) after 30 days at a health system level for a general population (under as well as over 65) was nearly USD 150,000 for the intervention relative to usual care group, resulting in cost savings averaging USD 412 per discharged person with RED.

Another example of a successful implementation of RED was reported by a pre-post study in a Texas hospital, utilising Medicare claims data, i.e. patients over 65 years, from the first quarter of 2008 (pre data) and the fourth quarter of 2010 (post data) (Markley et al. 2013). The initial target population were heart failure patients to be discharged to home care, and was later expanded to all inpatient units in that hospital. The hospital reported an 8.3 absolute percentage point reduction (from 23.3% at baseline to 15% at re-measurement) or a 36% relative reduction in its 30-day readmission rates. The study results are qualified to the extent of potential seasonal variation across different measured quarters and hospital discharge policies (education and planning) from early 2008 to late 2010. When comparing the fourth quarter of 2007 (October 1, 2007 to December 31, 2007) as the baseline with the fourth quarter of 2010, there was a 7.8 absolute percentage point reduction and a 34% relative decrease in hospital readmissions. Thus, better controlling for potential seasonal impacts suggest a marginally lower relative and absolute risk reduction. The intervention leveraged from the hospital with more appropriate care linkage across participating community's post-acute care providers, e.g. skilled nursing, inpatient rehabilitation and dialysis facilities and home health agencies in reducing 30-day hospital readmission rate. While hospital readmissions fell 7.8 percentage points in absolute terms the region's overall readmission rate of the hospitals and post-acute care providers dropped 2 absolute percentage points from 22% to 20%. The concurrent monitoring and collecting of data "as you go" was vital for the success of RED, as it allowed the hospital team to determine whether the intervention was effective in practice, or whether immediate changes were required.

These trial outcomes suggested RED to be effective and cost-effective, i.e. falling hospital readmission rates, implying better quality of care within hospital and beyond discharge, and thereby decreasing health care costs as well as improving the individuals' quality of life.

Unpublished data from the RED project at the Boston Medical Centre identified that patients in the usual care group were unprepared for discharge. The hospital staff spent an average of 8 minutes on discharge, with the patient being a passive recipient of information 84% of the time rather than having a "teach back" method in place. (Jack 2016). Unpreparedness of patients at discharge was also reflected in patients being unable to demonstrate an understanding of the treatment, processes or appointments post discharge. In usual care previously, 63% of patients were unable to state the purpose of their discharge medications and how to take them, and 58% were unable to state their treatment plans and diagnosis at discharge (Makaryus and Friedman 2005). The RED intervention successfully improved patient's self-reported preparedness for discharge and knowledge of discharge diagnosis, as well as the frequency of PCP follow-up visits (Jack et al. 2009).

The Australian ACACIA (management of acute coronary syndromes) registry similarly shows a rapidly diminishing proportion of patients on the right medications from post discharge to 12 months follow-up (Chew et al. 2008). This finding reflects patient's lack of health literacy and understanding on how to navigate the care post discharge appropriately. That management process also lacks connection to the PCP (usually the GP) as an agent to help in the discharge process to ensure ongoing care and facilitate access to effective strategies and health care services. Recommendations arising from the ACACIA study in Australia included a more systematic handover and follow-up of patients with their GP as part of monitoring the appropriateness of post-acute care, rehabilitation and medication use (Brieger et al. 2009). Hence, the ACACIA evidence in Australia presents a similar situation with regard to inadequate patient information and understanding, as well as lack of connection to PCPs, as was seen in the usual care arm of the RED study (Jack et al. 2009). Consequently, the impact of RED on usual care practice in Australia can be expected to be similar to the reported benefits in the US.

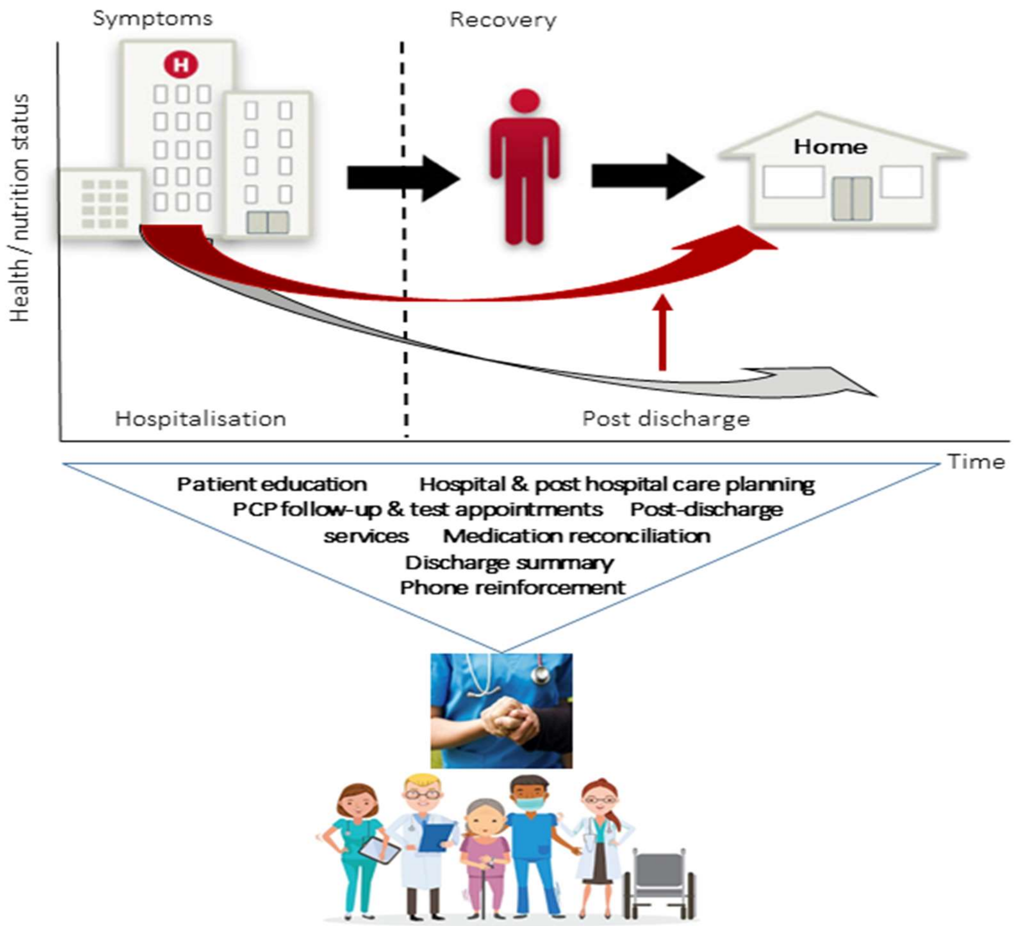
The RED care model focuses on improving patient access to primary health care services while still in hospital, so that the care plan can be translated to the post discharge care setting.

Social determinants of care (i.e. lifestyle, environmental and risk factors) such as burdensomeness, patient activation, housing, hospital communication, understanding medications, PCP involvement, social network, isolation/loneliness, substance abuse, financial constraints, mood, pain management, transportation and access to healthy foods are key for an older malnourished persons recovery and can be related to adverse events and hospital readmissions after discharge. Frail older adults, particularly those who are socially isolated and have low incomes, are at greater risk of food insecurity (Russell et al. 2016). The authors provided evidence that food insecurity and poor diet quality were associated with reduced quality of life in community-living older adults. Food insecurity can lead to malnutrition both in terms of under- and overnutrition. Services that consider socio-demographic and health factors, e.g. the older person's physical limitations (mobility), mental/emotional health, chronic disease status, financial status (Quine & Morrell 2006), social status/support or even health-related quality of life (Campbell 1991), should be considered in the discharge planning process to reduce food insecurity in community-dwelling older populations.

RED makes better hospital discharge a priority and enables better post-discharge care by linking hospital and primary care providers in the community and aged care, for improved integration of health and aged care. The RED discharge nurse advocate ensures a better coordination with nurses and doctors to create and teach a comprehensive discharge plan with a focus on medical as well as social-centred patient care (Jack et al. 2008). Many of the social determinants associated with nutritional status, e.g. housing, social networks, and access to healthy foods are amenable to improvement from the RED strategy. The establishment of a strong hospital team with support from multiple departments including the hospital management and administration have proven to be effective components in implementing the RED intervention. A strong leadership with nurses and clinicians being aware of their responsibilities and adequate communication among the team members, the patients and their careers have played a major role. Also the engagement of the hospital with the post-acute care providers has shown to be more successful in facilitating continuous post-discharge care than implementing RED in the hospital alone (Jack et al. 2008, Markley et al. 2013).

Based on its proven success in US hospitals (general hospital and Medicare patient populations), the RED care model is used as an alternative hospital care and discharge strategy in this thesis in modelling its expected impact when compared to usual acute care hospital practices in Australia. RED can be expected to be particularly valuable for malnourished older hospital patients given their need for a timely identification of malnutrition as well as better coordination and access to appropriate integrated care (Fig. 2.1). Hence, RED provides a promising model for higher quality of patient care within and beyond hospital separation in jointly addressing health system effects and costs.

Fig. 2.1 Re-Engineered Discharge (RED) care model linking the older person's hospital medical care with health and nutrition care as well as primary care in the community



2.7 Research questions and hypotheses

The research questions from a health economics point of view are:

1) To what extent the RED care model is expected to reduce rehospitalisation and associated downstream costs in the Australian aged (over 65) population with malnutrition relative to current usual care?

2) Whether the RED care model is incrementally cost-effective – has incremental net benefit in this Australian target population - from a health system perspective given the expected direct and downstream costs and effects?

It is hypothesised that the RED care model enables appropriate hospital and health system care pathways for addressing malnutrition in older populations presenting in hospital. This includes appropriate dietary education in the hospital and risk minimisation in the community for social determinants and is hypothesised to lead overall to both a better health status and lower treatment costs over time in care of older malnourished acute care patients. The dietary care and other aspects of care such as medication plan are further hypothesised to be best reinforced by the PCP, whilst recognising that the primary carer, who can also be a family member for those discharged home or a residential aged care worker for those going to residential aged care, is likely in a better position to manage the older person's care needs. Overall, it is hypothesised that the RED care model will be incrementally cost-effective in this population from a health system perspective given its expected direct and downstream cost savings and effects.

3 METHODOLOGY

This methodology chapter outlines the overall research design and includes:

(i) Selection of a homogenous Australian population to later enable robust consideration of nutrition status and usual care baseline risks in over 65 patients presenting in hospital for joint cost, effect and cost-effectiveness analysis (CEA);

(ii) Estimation of 12-month survival and rehospitalisation cost (resource use) analysis in that population from linked patient level admission data by DRG conditional on nutritional status;

(iii) Modelling of the natural history of older acute care patients conditional on being malnourished given current dietary treatment pathways. The model reflects best nutrition care practice in treating malnourished ill older Australian patient populations that presented in hospital in 2009/10;

(iv) Robust evidence synthesis of the treatment effect (RED study) with the Australian usual practice natural history model for older malnourished patients presenting in acute hospitals to inform expected incremental health care (combined hospital base admission, rehospitalisation and GP) costs with RED relative to usual practice in that study population; and conservative cost effectiveness analysis assuming no associated health or aged care benefits;

(v) Sensitivity analyses applying the RED treatment effect to malnutrition status to allow for incremental survival and aged care use effects conditional on nutritional status impacts given REDs expected improvement in hospital and post discharge nutrition care.

In general, the modelled CEA allows an extension of Charlton’s (2013) within-study clinical analysis according to malnutrition subgroups. The decision analytic modelling of health or wider public policy consideration using decision trees is conducted in five stages: 1) Identifying and bounding the problem using the PICO (Patient, Intervention, Comparison, Outcome) framework (Huang et al. 2006), 2) Structuring the tree as well as 3) Populating the tree applying health economic coverage and comparability principles, 4) Analysing the tree and 5) Undertaking sensitivity analysis to allow for uncertainty. Bayesian methodology to inform screening and diagnosis policy are also considered.

3.1 Overview of the clinical evidence

For baseline modelling of usual care, a retrospective CEA is undertaken utilising deidentified electronic nutritional and other medical records of patients aged 65 years and older. These patients were admitted to the acute care wards of the study hospital, a major tertiary care referral hospital in the Illawarra Shoalhaven Local Hospital District of regional New South Wales between 1st January 2009 and 31st December 2010 with linked data allowing for 12-month follow-up from date of index admission in all patients. The hospital dataset includes vital admission, diagnostic and therapeutic information related to every patient's hospital visit, including patient demographic details (e.g. gender, age, height, weight, BMI), Major Disease Classification ((MDC), used as a proxy for underlying illness), number of hospital admissions (index admission and subsequent readmissions), number of Emergency Department presentations, length of hospital stay (LOS), final discharge destination, change of level of care compared to index admission, in-hospital death as well as cost weights assigned for each admission. In the original clinical study of Charlton et al. (2013), these patient records had been retrieved, cross-referenced and merged with routine Mini Nutritional Assessment (MNA) data from a database actively maintained by the Department of Nutrition and Dietetics at the same hospital. Ethics approval for this clinical study was obtained from the University of Wollongong Human Research Ethics Committee and site specific approval from the South Eastern Sydney Illawarra Area Health Service. External researchers were added to ethics and appropriate approvals obtained for the subsequent health economic analysis. Table 3.1 shows some of the admission characteristics of the total 12-month study population as used by Charlton and colleagues, including anthropometric indices and nutritional status.

The health economic analysis extends Charlton's within-study clinical analysis by malnutrition subgroups and main MDC categories, which included a total sample of n = 774 older acute care patients (Table 3.1) and analysed health outcomes by nutritional status. In that study, which adjusted for underlying illness (primary MDC on hospital admission) and age, significant associations were demonstrated between nutritional status (being malnourished, at risk or well-nourished, assessed with the MNA tool and MNA scores defined in Table 3.1) and clinical outcomes within a 12-month period of follow-up from date of index admission. The clinical outcomes investigated were total LOS, in-hospital mortality and discharge to a higher level of residential care.

Table 3.1 Admission characteristics of the total 12-month study population, including anthropometric indices and nutritional status

Characteristic		Total study population
		N = 774
Age (years)	N	774
	Mean (SD)	83.5 (7.3)
	Median (IQR)	84.2 (79.1, 88.5)
Gender (%)	N	774
	Male	37.7
	Female	62.3
BMI (kg/m2)	N	728
	Mean (SD)	23.5 (5.2)
	Median (IQR)	23.0 (20.0, 26.0)
MNA score	N	774
	Mean (SD)	18.5 (4.8)
	Median (IQR)	19.5 (15.5, 22.0)
Number of admissions	N	774
	Mean (SD)	1.80 (1.24)
	Median (IQR), max	1 (1, 2), 10
Number of ED presentations	N	774
	Mean (SD)	0.51 (1.07)
	Median (IQR), max	0 (0, 1), 12
Total length of stay (days)	N	774
	Mean (SD)	41.3 (34.9)
	Median (IQR)	33.5 (15.0, 56.0)

SD (Standard deviation), IQR (Interquartile range), BMI (Body Mass Index), ED (Emergency Department), MNA (Mini Nutritional Assessment) score: Malnourished (score < 17); at risk of malnutrition (17 - 23.9); and well-nourished (≥ 24) (Guigoz et al. 1994).

3.1.1 Selection of a homogenous base case population

One key issue that arose in Charlton’s (2013) within-study clinical analysis was patient heterogeneity within two of the five MDC groupings, when merging nine MDC categories into five for the purpose of their regression modelling (Table 3.2). While orthopaedic conditions were the reason for the highest proportion of index hospital admissions, accounting for 40.6% (314 patients) of all 774 patients, followed by respiratory conditions with 13% (101 patients) other medical conditions represented 11.6% (90 patients). The category ‘other’ represented a widely heterogeneous sample and included patients with cancer, multiple co-morbidities, anaemia, and post-operative complications. To this were added diabetes, gastrointestinal and renal conditions in collapsing from nine to five MDCs. The falls category was merged with acopia/syncope/frailty and neurology was included in the cognitive category while the cardiac conditions were included in 'other'.

In order to minimise heterogeneity that could conflate relative cost and effect relationships by malnutrition status, and to jointly consider policy relevant survival effects and costs of readmissions up to 12 months across different nutritional states (malnourished, at risk, well-nourished), health economic analysis was restricted to a more homogenous and standardised population. The current study focusses on only the three largest MDC categories that were the predominant cause of the index hospital admissions of the older study population in 2009/10, namely, 1) orthopaedic conditions (40.6%), 2) respiratory conditions (13%) and 3) falls (8.5%) (Table 3.2). The heterogeneous 'other' category was excluded. This resulted in a smaller sample size than the original cohort, but substantially more homogenous sub-population of 481 older patients that collectively account for 62% (481) of the 774 hospital admissions analysed by Charlton et al. (2013). Importantly, these patient groupings enable standardised analysis, adjusting for differences in nutritional status and admissions across MDC categories in satisfying comparability. Hence this standardised approach improves homogeneity to allow comparability for a robust health economic analysis of joint health, resource use and cost impacts according to malnutrition status and their subsequent incremental costs and CEA considerations comparing the RED care model with usual care.

Table 3.2 Major Disease Classification (MDC) categories mainly responsible for hospital admissions of the older 12-month study population in 2009/10

Major Disease Classification (n, %)	Collapsing 9 into 5 MDC categories*	3 MDC sub-sample (as in thesis)
Orthopaedic	314 (40.6)	314 (65.3)
Respiratory	101 (13.0)	101 (21.0)
Other	90 (11.6)	
Falls	66 (8.5)	66 (13.7)
Acopia/Syncope/Frailty	51 (6.6)	
Cognitive	44 (5.7)	
Cardiac	42 (5.4)	
Renal	28 (3.6)	
Gastrointestinal	25 (3.2)	
Neurology	9 (1.2)	
Diabetes	4 (0.5)	
Total	774 (100)	481 (100)

* MDC grouping based on Charlton et al. (2013)

In the homogenous sub-sample of 481 patients, 32% of the older adults were malnourished, 55% were at risk of malnutrition and 13% were well-nourished (Table 3.3). Similarly, in Charlton's (2013) study population of 774 patients, 34% of the older adults were malnourished, 55% were at risk of malnutrition and 12% were well-nourished. Charlton et al. (2013) conducted binary logistic regression analyses controlling for age and underlying illness (MDC category) and using the well-nourished patient group as their reference for the variable of nutritional status (MNA category). Malnutrition in older acute care patients predicted adverse clinical outcomes and mortality within 12-months follow-up. They also showed that the older acute care patients at risk of malnutrition ($17 < MNA < 24$) were 2.46 ($p = 0.003$) times more likely, and those malnourished ($MNA \leq 17$) 3.57 ($p < 0.001$) times more likely to have an adverse clinical outcome (increased level of care on discharge and mortality versus no change), than well-nourished ($MNA \geq 24$) older patients.

Table 3.3 Major Disease Classification (MDC) data according to MNA categories

MDC	Malnourished (MNA < 17) n = 155 (32.2%)	At risk of malnutrition (MNA = 17 - 23.9) n = 262 (54.5%)	Well nourished (MNA ≥ 24) n = 64 (13.3%)	Total n = 481
Orthopaedics	88	178	48	314
% within MDC	28.0	56.7	15.3	100.0
Respiratory	40	51	10	101
% within MDC	39.6	50.5	9.9	100.0
Falls	27	33	6	66
% within MDC	40.9	50.0	9.1	100.0

MNA (Mini Nutritional Assessment)

Employing evidence triangulation processes, results are assessed jointly, considering a more homogenous MDC grouping, with the initial study results with greater overall numbers while heterogeneous MDC groupings, to consider the extent of their robustness more generally. Once estimates of effect and cost impacts conditional on nutrition status are established, forms of Bayesian decision analysis can be employed to estimate expected posterior impacts of policy relevant interventions such as RED conditional on prior probabilities. That is the treatment effect of the RED care model directly on health effects and downstream costs via nutrition status (see sensitivity analysis). Such analysis can in turn provide an evidence basis to consider the appropriate care needs and potential of alternative practices in such populations.

3.1.2 Estimation of 12-months survival and rehospitalisation cost

3.1.2.1 Standardised odds ratio (OR) and Kaplan-Meier survival analyses

Survival analyses were undertaken to compare the 12-months clinical outcomes (i.e. in-hospital mortality, mortality or discharge to higher level of care, survival with increased level of care and survival with no change in care level) with the nutritional status (i.e. malnourished, nutritionally at risk and well-nourished) in older patients across the three MDC categories 'orthopaedics', 'respiratory' and 'falls' in the homogenous sub-sample and within each of these three MDC's. For the combined analysis across the three most common MDC's, it was standardised for each nutritional status across the MDCs. That is, the same proportions across MDC's were applied to malnutrition, at risk and well-nourished populations. These proportions were estimated by the population proportion in each MDC across combined nutritional states. After applying these proportions, the standardised (weighted) effects of nutritional status across the three MDC's were estimated.

Survival analysis was also conducted using Kaplan-Meier survival estimates as the standard method to examine the probability of death for differing survival times from study entry until death allowing for censoring of observed time (both administrative and any loss to follow-up) across patients (Rich et al. 2010). The survival time in the analysis of Charlton et al. (2013) was determined from entry into the study until the time of in-hospital death (time-to-event of interest) or the end of the study period - whichever occurred first for patients admitted within a two year period (1st January 2009 and 31st December 2010). Kaplan-Meier estimation in this thesis employs the same censoring method used in the Cox proportional hazards regression analysis by Charlton et al. (2013). Patients were accrued over the 1st January to 31st December 2009 period and observed over 12 months. The data has limitations in that only events within the index hospital admission are observed, and it is unknown whether patients died outside of hospital or if they were readmitted to another hospital over the 12-month follow-up. The survival function *S(t)* is estimated allowing for these limitations as the probability of survival past time t. In this dataset with observed survival times, $t_1, \ldots, t_k$, where k is the number of survival times observed, the Kaplan-Meier estimate at any time t is given by:

$$S(t_j) = \prod_{t_j \le t} \left(1 - \frac{d_i}{n_i}\right),$$

Where n_i is the number of patients at risk at time t_i and d_i is the number of survival at time t_i. The overall product represents survival time less than or equal to any time t.

The Kaplan-Meier survival curve plot shows the proportion of patients alive at each time point. The log-rank test was used to compare the survival time (curves) of the independent patient groups (malnourished or at risk of malnutrition versus well-nourished or malnourished versus not-malnourished) to ascertain whether they differed on average. This is a simple, non-parametric test with assumptions that censoring was random and that the relative risk of death between groups was constant over time (proportional hazards). The test ranks all the survival times and compares the observed and the expected rates. For each time point j, N_{1j} and N_{2j} are the number of patients 'at risk' at the start of the study period j in the two patient groups, where $N_j = N_{1j} + N_{2j}$. The observed number of deaths across both groups at time j is defined as $O_j = O_{1j} + O_{2j}$. According to the null hypothesis that the death rates in both patient groups are equal, O_{1j} has a distribution with the parameters N_j, N_{1j} and O_j with an expected value

$E_{1j} = O_j/N_j * N_{1j}$

and a variance

$$V_j = \frac{O_j(N_{1j}/N_j)(1 - N_{1j}/N_j)(N_j - O_j)}{N_j - 1}$$

The following log-rank statistic comparing each observation O_{1j} to its expectation E_{1j} is defined as:

$$Z = \frac{\sum_{j=1}^{J}(O_{1j} - E_{1j})}{\sqrt{\sum_{j=1}^{J} V_j}}.$$

Thus, the test compares the survival time (curves) of the two independent patient groups (malnourished versus not-malnourished) to see whether they are different on average.

3.1.2.2 Cost assessment

Hospital readmission is a key driver of costs and is one of the consequences of disease-related malnutrition in the absence of appropriate care from within to beyond hospital admission. For this reason, hospital readmission data was used, both as a measure of cost implications and as a clinical outcome, to estimate the impact of alternative hospital care and post-discharge strategies on disease-related malnutrition. Hospital utilisation and its associated costs were calculated from linked patient-level, 12-months cost of hospital inpatient care data by DRG and cost weight. Hence, costs reflect the average total costs of all of a patient's acute care hospitalisations within 12 months, including the index hospital admission and all subsequent in-patient readmissions for the study duration. Outpatient clinic events, comprising subacute (i.e. rehabilitation and palliative care as well as geriatric evaluation and management care) and non-acute (i.e. maintenance care) care type episodes, were not included in the available dataset and hence cannot be considered in the total hospital and non-hospital costs. DRG cost weights applied to admissions accounted for the costs of allied health professionals such as the hospital dietitians and discharge planners (i.e. a registered nurse or clinical nurse consultant), but not for the specific individual nutritional treatment. Since dietitians use individualised therapy as opposed to a predetermined treatment protocol, food and supplements are generally seen as an overhead cost of the hospital and apportioned to all patients according to their length of stay. The cost weights employed for DRG's measured in the retrospective dataset reflected the estimated value of the relative resource requirements for any given admission type, where the total costs (excluding Emergency Department costs) were calculated based upon the current cost of care standards.

The expected total amount of direct intervention medical costs associated with malnutrition reflected both medical and nonmedical care expenditures related to a disease state. This included the salary for hospital staff including a discharge planner in the RED (Re-engineered discharge) arm. These salary costs were derived from local prices and official tariff lists from 2009/10. Australian prices were applied to expected staff time in the RED and usual care arms. Discounting of costs and effectiveness measures was not performed as the time horizon of the model did not exceed 12 months. Direct nonmedical costs such as costs to patient and their family/caregivers who supported the patient were not taken into account, following PBAC guidelines (PBAC 2008). The analysis was conducted from an Australian health and aged care system perspective and led to an Australian health system cost analysis by valuing health care resources at their relevant prices, in line with PBAC guidelines. It did not include wider societal costs such as carer burden or productivity loss, while noting, that given the age of the patient population, most were likely to be retired.

By applying the treatment effect of the RED hospital care and discharge strategy, RED has direct intervention costs that are expected to be offset to a greater or lesser degree by a reduced hospital readmission rate. For the natural history arm in the decision tree model, a top-down estimation method was applied where the average costs of a disease per admission in the dataset was calculated based on the Australian National Hospital Cost Data Collection (NHCDC).

A bottom-up method was used to estimate the direct intervention costs of the RED strategy arm in the decision tree model. This considered the time that the discharge planners typically spend with the patient and the rest of the hospital team to coordinate hospital care and discharge, and this time was applied to the cost of wages for those health professionals.

The top-down and bottom-up cost estimates were calibrated and combined, then extrapolated to a population level.

3.2 Modelling approach

The Re-Engineered Discharge (RED) model of care was identified from current literature as preferred hospital care and discharge strategy. The modelling aim is to consider incremental cost and effect impacts of RED for malnourished ill older patients in attempting to provide 1) an adequate and timely treatment of hospital malnutrition (i.e. nutritional intervention) within the hospital including a comprehensive discharge plan and 2) an appropriate follow-up care in the post-discharge setting. The RED care model applied to usual care in Australia involves the discharge planner working closely with clinical staff, dietitians and nurses to educate and provide nutritional and medical care within the hospital and set up the patient's care pathway for post hospital discharge. After discharge, the RED model's aim in the malnourished target population is to educate, prepare and encourage the patients to follow up with primary care providers (PCP) until they recover from their malnourished state.

A conservative modelling approach in considering the RED strategy was applied, assuming that all bottom-up estimates were incremental and not substituting for any other provided care and related process. Decision analytic methods are employed to systematically combine estimates of epidemiological and health system resource use reflecting current practice in malnutrition populations in Australia with evidence on the effectiveness of the RED care model. This can better inform societal decision making in relation to incremental cost-effectiveness of the proposed intervention based on current evidence, and to identify where further research is needed.

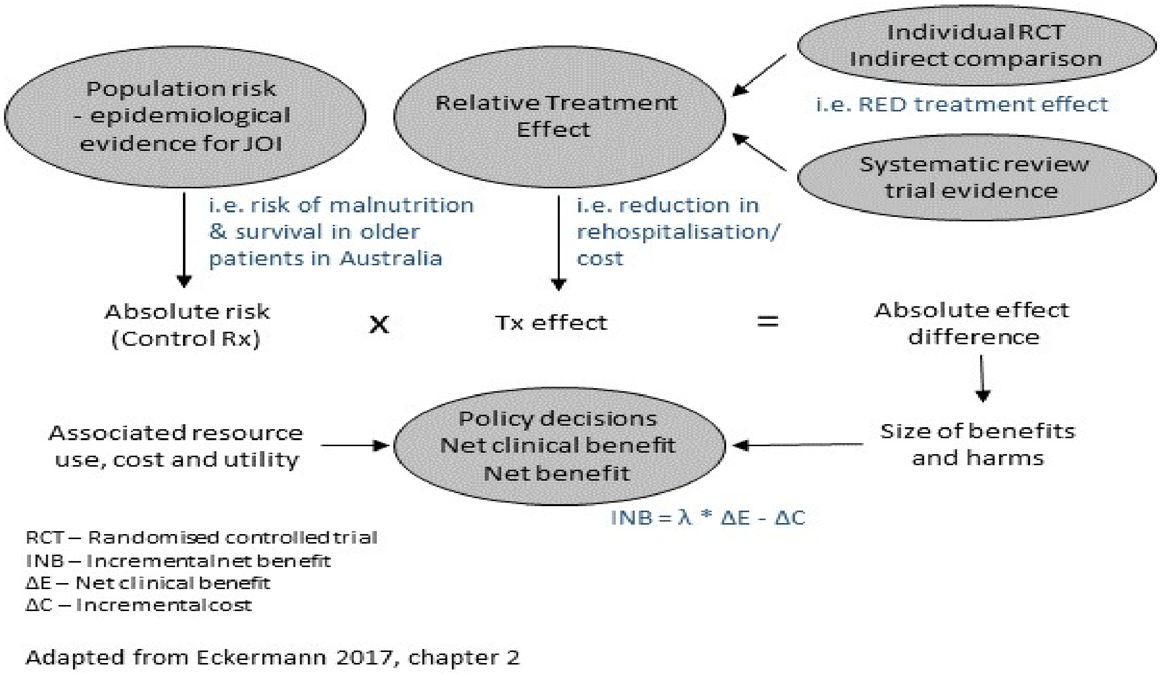
3.2.1 Evidence synthesis to inform decision making

The decision analytic modelling focused on expected incremental RED costs with prior probabilities of readmission in the base case, modified by the RED treatment effect on readmissions, and potential associated incremental nutrition-related survival and aged care use effects in sensitivity analysis. These analyses allow consideration of the association between suboptimal policies for addressing malnutrition in older acute care patients and adverse clinical effects in patient populations over time, including hospital readmission and in-hospital mortality rates. Such analysis synthesises the most relevant evidence – to address optimal policy decision making given conservative base case analysis while considering uncertainty in sensitivity analysis and consideration of further research.

In order to inform the net benefit for the Australian population of interest, known Australian estimate of the population's baseline risk (i.e. epidemiological risk) of malnutrition and of survival (hospital dataset by Charlton et al. 2013) is used. This enables applying the relative treatment effect of RED for reduced rehospitalisation and associated costs, informed by randomised controlled trial (RCT) evidence from the literature (Jack et al. 2009), to the hospital study data from malnourished ill older patients to obtain conservative estimates of absolute effect differences. These results can be combined to estimate INB allowing for the value of incremental effects less their incremental costs.

Figure 3.1 adapted from Eckermann (2017) is instructive in considering such evidence synthesis to inform decision making for the jurisdiction of interest, Australia.

Fig. 3.1 Decision making for a jurisdiction of interest (JOI), e.g. Australia with its health system practice



3.2.2 Capturing incremental health effect and cost impacts of the RED care model

Decision tree models have been developed to estimate the cost-effectiveness of the RED model of care to manage poorly nourished ill older patients within the acute hospital and post-discharge setting from an Australian health and aged care system perspective. The models reflect current practice of in-hospital care and discharge processes for older patient populations presenting in Australian acute care hospitals. The models translate the synthesised clinical evidence on Australian usual care (Charlton et al. 2013) and health economic evidence of the RED treatment effect on reductions in rehospitalisations to reflect better coordination and use of primary care post-discharge (Jack et al. 2009). The usual care natural history basis for the decision analytic modelling includes resource and health outcome effects (rate of in-hospital readmissions and survival) that are associated with the nutritional status. This information is used to model the estimated impacts of malnutrition and thereafter assess the benefits of the care models to modify malnourished states over time in current practice.

The initial patient population-centered research question of interest is whether there are net cost (in index hospital admission and in admissions over 12 months) savings associated with malnutrition in older patients (65 years and over) presenting in hospital, given practice evidence of current health service use. This enables building to later consideration of incremental survival effects and aged care costs conditional on potential nutritional status impacts of the RED model of care.

3.3 Model structure

The decision tree models were constructed in TreeAge Pro 2017 software (TreeAge Software Inc, Williamstown, MA, USA). The trees usually begin with a decision node represented by a square (□) and reflecting a treatment choice, in this case, "usual care Australia" or "RED model". Figure 3.2 shows the overall structure and Table 3.4 the parameters of the decision tree model used to undertake the incremental CEA. Modelling employs the PICO framework as well as the health economic coverage and comparability principles. Usual care in Australia is compared to the RED model of care in an older hospital patient population to address malnutrition within the hospital and aid in care and dietetic process coordination of discharging malnourished patients from hospitals back into the community setting. The decision tree shows simplified pathways of older patients identified as malnourished, at risk or well-nourished to the point of final discharge destination (i.e. whether an older patient was discharged home after the last hospital separation, to low level (hostel) or high level (nursing home) care or died in hospital). The patient's nutritional status is represented with a chance node shown in the tree as a circle (○). The discharge destination is represented with a terminal node shown as a triangle (Δ) with associated payoffs for resource use/costs and health effects conditional on the clinical pathway. As shown in Figure 3.2, the total costs in the RED arm are obtained by multiplying the readmission cost in Australian usual care for each pathway with the RED relative risk of 0.696. Then, the cost for the days spent in aged care are added to all pathways where patients were either discharged to low or high level of care after their final hospital discharge.

Fig. 3.2 Decision tree reflecting usual care practice in Australia to address hospital malnutrition in older patients modified by the RED relative treatment effect (RR_REDTx) on post discharge hospital use

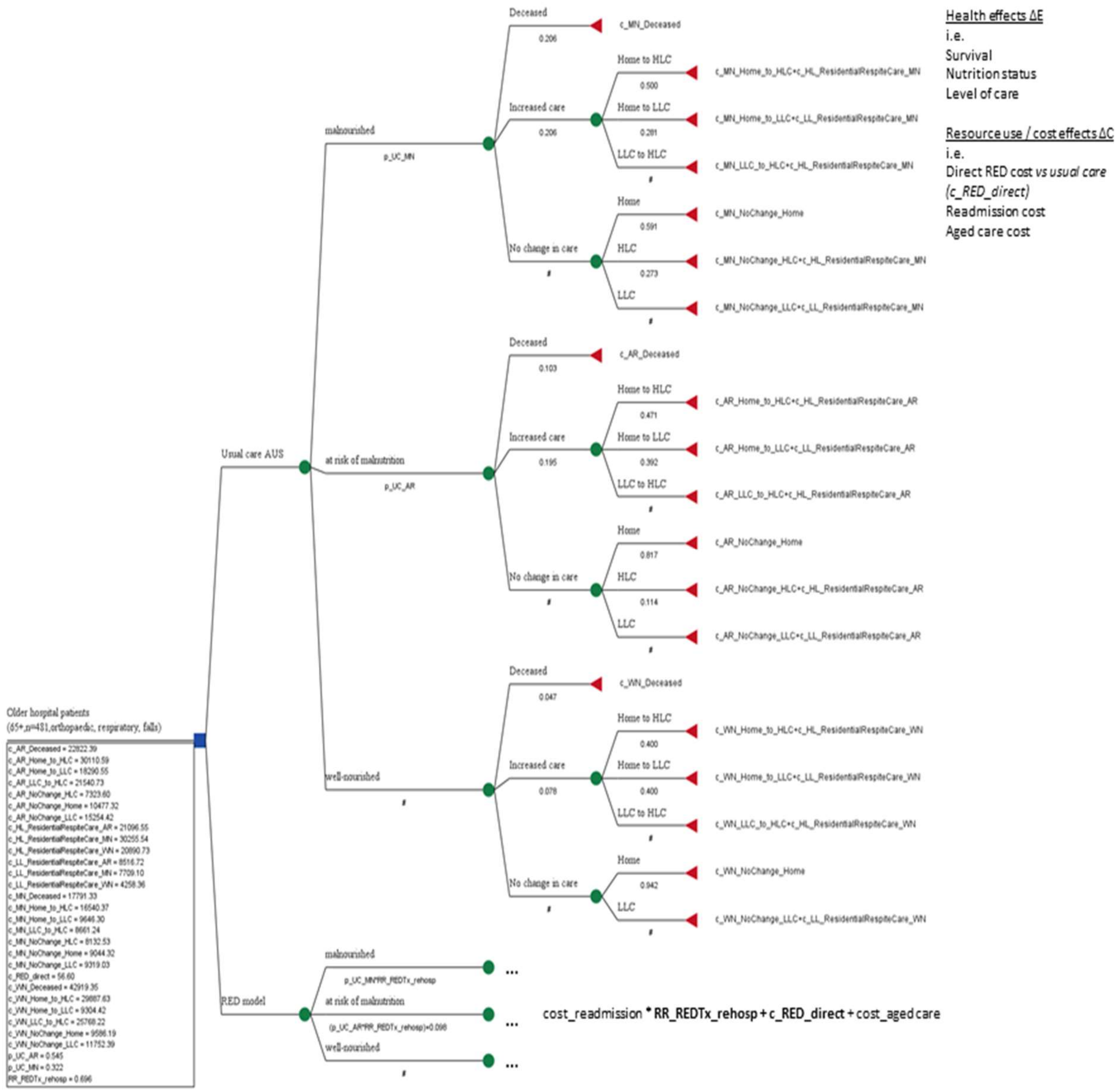


Table 3.4 Summary of parameters used in the decision tree reflecting Australian usual care practice

Name	Description	Mean value (AUD)
Malnourished (MN)		
c_MN_Deceased	Cost (c) readmission - malnourished deceased patients	17,791.33
c_MN_Home_to_HLC	Cost readmission – malnourished, discharged from home to high level care (HLC)	16,540.37
c_MN_Home_to_LLC	Cost readmission – malnourished, discharged from home to low level care (LLC)	9,646.30
c_MN_LLC_to_HLC	Cost readmission – malnourished, discharged from low to high level care	8,661.24
c_MN_NoChange_HLC	Cost readmission – malnourished, discharged from high to high level care	8,132.53
c_MN_NoChange_Home	Cost readmission – malnourished, discharged from home to home	9,044.32
c_MN_NoChange_LLC	Cost readmission – malnourished, discharged from low to low level care	9,319.03
At risk (AR)		
c_AR_Deceased	Cost (c) readmission – at risk deceased patients	22,822.39
c_AR_Home_to_HLC	Cost readmission – at risk, discharged from home to high level care (HLC)	30,110.59
c_AR_Home_to_LLC	Cost readmission – at risk, discharged from home to low level care (LLC)	18,290.55
c_AR_LLC_to_HLC	Cost readmission – at risk, discharged from low to high level care	21,540.73
c_AR_NoChange_HLC	Cost readmission – at risk, discharged from high to high level care	7,323.60
c_AR_NoChange_Home	Cost readmission – at risk, discharged from home to home	10,477.32
c_AR_NoChange_LLC	Cost readmission – at risk, discharged from low to low level	15,254.42
Well-nourished (WN)		
c_WN_Deceased	Cost (c) readmission – well-nourished deceased patients	42,919.35
c_WN_Home_to_HLC	Cost readmission – well-nourished, discharged from home to high level care (HLC)	29,887.63
c_WN_Home_to_LLC	Cost readmission – well-nourished, discharged from home to low level care (LLC)	9,304.42
c_WN_LLC_to_HLC	Cost readmission – well-nourished, discharged from low to high level care	25,768.22
c_WN_NoChange_Home	Cost readmission – well-nourished, discharged from home to home	9,586.19
c_WN_NoChange_LLC	Cost readmission – well-nourished, discharged from low to low level care	11,752.39
c_RED_direct	Direct cost of RED – discharge planner wage level plus on-cost	56.57
Probabilities		
p_UC_MN	Probability to be malnourished in usual care (UC)	0.322
p_UC_AR	Probability to be at risk of manlutrition in usual care (UC)	0.545
RED treatment effect		
RR_REDTx_rehosp	Relative risk (RR) of rehospitalisation	0.696

Malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment)

3.3.1 In-hospital care process – Natural history model

The natural history model tree (see Results, section 4.2.1, Fig. 4.3) considers current nutrition care practice in the acute hospital up to the point of hospital discharge for malnourished or at risk older patients admitted to hospital with orthopaedic, respiratory or falls diagnosis. The focus in this tree is evidence synthesis for patient pathways that treat disease-related malnutrition within the health care system. The in-hospital clinical pathways were established in conjunction with an experienced clinical dietitian who has worked closely with older inpatients who have been malnourished or at risk of malnutrition, and represents usual care practice in a real-world setting.

The inverted decision tree model (applying Bayes method, see Results, section 4.2.1, Fig. 4.4) reflects the current nutrition screening practice in usual care for older acute hospital patients. In this tree, the two nutrition screening tools used for older acute care patients in the study hospital are compared to estimate expected costs and effect changes in hospital and community. This information aids in allocating the scarce hospital resources to those patients that are malnourished.

3.3.2 Re-engineering the discharge process – Extrapolated model

The in-hospital pathways for the study population lead to the probability of being discharged home, to low or high level care, transferred to another hospital or of in-hospital death, represented as part of payoffs at terminal nodes.

The subsequent decision trees (see Results, section 4.2.3 and 4.2.4, Figs 4.6, 4.7, 4.8. 4.9) consider an extrapolated model comparing the usual discharge process for malnourished ill older patients with the proposed RED discharge strategy. It incorporates the medication-related and dietary-related processes of RED and usual care, respectively. This represents an incremental comparative health system analysis, where usual care reflects the hospital system analysis in the first part of the tree, extended to policy and down-stream analysis in comparing usual care to the RED strategy. The second part of the decision tree considers the incremental impacts (health effects and costs) of the RED care model in modifying current treatment practice in hospital and post-discharge. The expected hospital cost over 12 months (index admission and hospital readmissions) are included for each terminal node pathway. The tree synthesises and translates the relative treatment effect based on the RED trial evidence to modify the Australian usual hospital care and discharge practice. Undertaking such evidence translation consistently for binary outcomes (e.g. survival, mortality; readmission or no readmission; progression, no progression etc.) requires the use of OR (Eckermann et al. 2011) rather than relative risk. This enables consistent estimation of incremental absolute effect differences with alternative framing of binary outcomes and associated treatment costs and incremental cost-effectiveness.

3.4 Model data inputs

Decision trees are populated with evidence of probabilities of the health and cost outcomes along the pathways and with outcome values for health and costs (i.e. resource use multiplied by prices) over time given the pathway. Probabilities within a tree are conditional on the previous pathways and events. That is, the conditional probability of one event A given another event B has occurred, written as *P[A|B]*. All probabilities behave in the same way when analysing (rolling back or averaging out the expected payoffs by alternative treatment arms and their respective pathways in) the tree. The tree structure requires that probabilities of all events at chance nodes are mutually exclusive and exhaustive, i.e. sum to 1. The expected outcome value at a chance node is the sum of probabilities multiplied by the outcome value across the mutually exclusive and exhaustive set of outcomes:

Outcome value (A) x p(A)
+
Outcome value (B) x p(B)
+
Outcome value (C) x p(C)

The types of data populated in the decision tree models included clinical probabilities, survival and resource utilisation, such as the number of hospital admissions (excluding Emergency Department visits) and hospitalisation costs. Literature searches were performed using the terms "older patients", "malnourished", "hospital", "discharge", "orthopaedic", “respiratory” or "falls" in order to ascertain input values for the model parameters. The data sources used to populate the models were based on data obtained from the hospital medical and nutritional database and clinically informed estimates of two hospital dietitians (i.e. expert opinion), as there was limited information in the literature on malnourished older patients with conditions related to the three chosen MDC categories. Other treatment probabilities, i.e. the RED relative treatment effect on reduction in hospital utilisation and readmissions, were determined from literature published by Jack and colleagues. ORs were applied for binary outcomes (survival) to the baseline risk of the hospital patient population to consistently model the malnutrition treatment effects on absolute incremental survival (Eckermann et al. 2009, 2011).

3.5 Analyses around the conservative base case

Once the expected values at each outcome and chance node were calculated, the tree was analysed by rolling back expected values from right to left. At each decision node, the optimal pathway was chosen and the other pathways pruned until the original decision node was reached and the optimal pathway identified. Using a natural history model with clinical evidence of Australian usual care practice, expected health outcome, resource use and costs were estimated for treating ill older patients in the acute setting, conditional on being malnourished, at-risk or well-nourished. The RED treatment effect on reductions in rehospitalisation, and more generally better coordination of care and use of primary care (RED study evidence), was applied (translated) to Australian usual care. The incremental effects, costs and cost-effectiveness of usual care practice were then compared with the RED care model for older patients with malnutrition, conditional on scenarios for relative treatment effects between the RED care model and usual care practice.

A conservative incremental cost-effectiveness base case was assumed:
(i) where the RED care model has only benefits in terms of cost reductions from readmissions avoided, but no nutrition or survival effect benefits of RED or morbidity reduction,
(ii) with no direct cost offsets for the RED care model, i.e. it is incremental rather than substituting for usual care cost and
(iii) with no downstream aged care cost savings (see Results, section 4.2.3). That is in relation to less robust estimates of treatment effect on nutritional status and on what would be expected for both survival and aged care use, given the evidence of relative impacts by nutritional status in the analysis of data arising from Charlton’s study (2013).

3.5.1 One-way sensitivity analysis

One-way sensitivity and threshold analysis were undertaken to allow for stochastic and scenario related decision uncertainty.

To allow for decision uncertainty around base case CEA, one-way sensitivity analyses were used to consider varying base case assumptions, variable ranges across parameter estimates or tree structure and whether a decision changes or is robust to such uncertainty. If the conclusion remains unchanged the result can be seen as robust. Where results are not robust, sensitivity analysis can identify areas where more information through further research is required.

Two sensitivity analyses around the conservative base case were performed (see Results, section 4.2.4). In the first sensitivity analysis, the RED treatment effect on reduction in rehospitalisations (RR of 0.696) is used as a proxy for the RED treatment effect on nutritional status. Applying the RED treatment effect to the base risk of being malnourished and at risk of malnutrition has expected impacts on incremental costs as well as health effects, i.e. leading to improved health status in general both during and post hospital discharge.

In the second sensitivity analysis, the RED treatment effect was applied to the base risk of the nutritional status and costs of low level (hostel) or high level (nursing home) care that were included in this decision tree model, based on the older patients' final hospital discharge destination and the time of that discharge. The average daily subsidy rate for relevant low level or high level residential respite care were calculated based on 'Aged care subsidies and supplements', covering the payment rates from 1st July 2008 to 30th June 2012, Department of Health, Australian Government web archive.

3.5.2 Threshold analysis

Threshold analysis models the boundary conditions and identifies boundary values for variables under which decision making uncertainty arises or at what point the optimal decision changes. It can be used to identify the critical value of a parameter to be achieved for an intervention to be deemed as worth supporting, based on clinical or cost-effectiveness criteria. Decisions in relation to cost-effectiveness are made based on the differences in incremental net benefit at certain threshold values for the effects in the case of a CEA.

Although threshold analysis avoids issues of arbitrary endpoints for plausible ranges, it relies on a known decision making threshold and it does not map parameter to decision making uncertainty.

Threshold analyses were performed in relation to the RED relative treatment effect on reduction in rehospitalisations to determine what its threshold value would be for the RED care model to become cost saving to the health system in treating patients 65 years and older that present in the acute care hospital. The 12-month readmission cost and readmission and aged care use combined were considered.

3.5.3 Modelling under uncertainty

Decision tree models are necessarily based on simplifications of real life problems by making various assumptions and have representations of clinical pathways and uncertain parameters (probabilities and payoffs) that can change with different population, practices or preferences and potentially change optimal decisions. With modelling of alternate treatment for older patients with malnutrition (treatment) or at risk of malnutrition (screening / diagnosis), the focus of the current analysis is on factors and relationships expected to have the greatest impact on the health and cost implications. This aids in making informed decisions for the population of interest based on the likely major impacts across plausible scenarios. The uncertainty in model parameters, assumptions, populations and treatment pathways can result in different conclusions reflected in sensitivity and threshold analysis. It can also lead to decision uncertainty around the net benefit which may justify further research. Only a probabilistic sensitivity analysis truly allows the modelling of parameter uncertainty to decision making uncertainty in CEA. However, it was beyond the scope of this thesis to undertake full model probabilistic sensitivity analysis. Nevertheless, the uncertainty of the data is retrospectively accounted for by sensitivity and threshold analyses around a conservative base case analysis.

3.6 Policy considerations around malnutrition screening and diagnosis

Malnutrition screening is a prerequisite for detecting undernourished older inpatients or those at risk of malnutrition. The MST and the Mini-Nutritional Assessment - Short Form (MNA-SF) are considered quick-and-easy malnutrition screening tools developed for nurses to quickly and easily screen the nutritional status of a patient with questions most predictive of malnutrition (Neelemaat et al. 2011). Either the MST or the MNA-SF are used by dietitians and nurses at the hospital of interest, in part depending on the age of the patient. The MNA-SF has been developed specifically for older patients, whereas the MST is usually applied to the general medical hospital population. The MST and MNA-SF screening tool usually divide the screened patients into two categories, i.e. at risk of malnutrition or not at risk of malnutrition. Thereafter, all at risk patients are further assessed by the MNA to categorize them into malnourished, at risk of malnutrition and well-nourished.

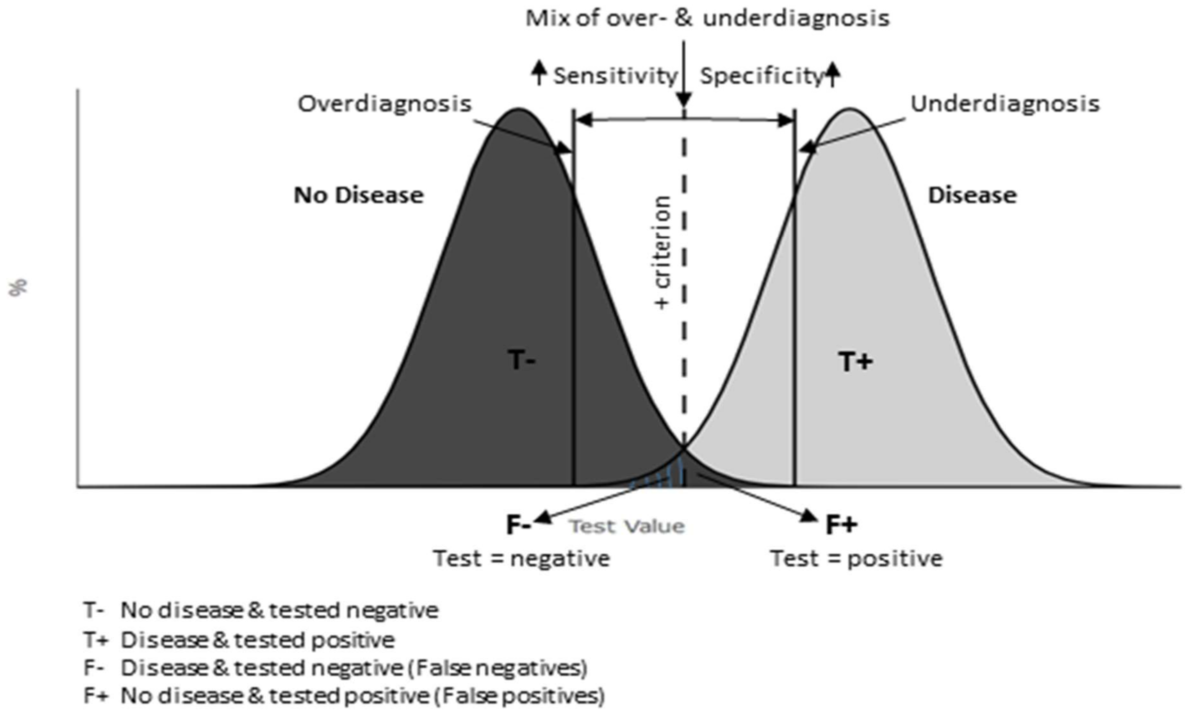
Including information from diagnostic and screening tests can aid in the decision making process by informing decision making under uncertainty about presence or absence of a disease, e.g. malnourished or not malnourished patients, or identifying those at risk of developing adverse clinical outcomes (Weinberg et al. 1980, chapter 4). Diagnostic tests can help guide treatment choices, i.e. referring those identified as malnourished and at risk for a more in-depth nutritional assessment with a dietitian. However, any diagnostic test or screening tool should be considered under uncertainty as such tests usually do not provide 'perfect information' with their separator variable criteria not perfectly distinguishing given variability in patient populations with and without the condition of interest. A test's performance can be characterised by its sensitivity and specificity. Sensitivity represents the probability (0–100%) of a test being positive given the disease is present (*P[T+|D]*), i.e. the malnutrition screening tool identifies malnourished patients correctly. Specificity represents the probability (0–100%) of a test being negative given the disease is not present (*P[T-|no D]*), i.e. the malnutrition screening tool identifies well-nourished patients correctly. A test might have a good sensitivity but poor specificity or vice versa depending on the choice of the positivity criterion for the separator variable. The separator variable is a measurable feature of the disease, e.g. low BMI and unintentional weight loss or screening test values to diagnose malnutrition. The positivity criterion is the cut-off point of the screening test values determining whether the test is positive or negative, e.g. ≤ 11 means malnourished or at risk of malnutrition and ≥ 12 points means well-nourished.

In Fig. 3.3, the sensitivity, specificity and choice of positivity criterion for diagnostic or screening tests is shown. The light grey area under the curve shows all patients tested positive (T+) and have the disease, called the true positives which represents the sensitivity of the test.

The dark grey area under the curve shows all patients that do not have the disease and tested negative (T-), called the true negatives which represents the specificity of the test. The shaded area shows all patients that have the disease but tested negative, called the false negatives (F-), and the unshaded area shows all patients that do not have the disease but tested positive, called the false positives (F+). When moving the cut-off point to the left, it increases the sensitivity and decreases the specificity by also increasing the number of false positives. On the other hand, when moving the cut-off point to the right, it increases the specificity at the cost of decreasing the sensitivity and also increases the number false negatives. In reality, there is a tradeoff between sensitivity and specificity, and one has to find a compromise at any given level of prevalence between the rate of patients who have the disease not being identified (false negative rate) and some patients who do not have the disease testing positive (false positive rate). The false positive rate *ceteris parabis* becomes more important when diseases are rarer or treatment for the disease is very invasive and/or expensive.

The sensitivity and specificity relate to the test performance depending on the presence or absence of the disease condition. For decision making it is important to know the probability of the disease conditional on the outcome of the test (*P[D|T+]*). Information on test characteristics and information on the probability of the disease (i.e. prevalence or *P[D]* from epidemiological studies, prognostic models or expert opinion) can be used to find *P[D|T+]*. The test results are then used to revise the prior probability (*P[D]*) of the disease to arrive at the posterior probability of the disease, i.e. malnutrition. The posterior or post-test probability of having malnutrition conditional on the test result can be calculated from the sensitivity and specificity of the malnutrition screening tool and the prior probability of malnutrition applying Bayes formula (whether directly, using odds-likelihood ratio formula, Nomograms or inverted decision trees).

Fig. 3.3 Sensitivity, specificity and choice of positivity criterion for screening test



A diagnostic test and the information it provides has the potential to reduce uncertainty of the presence or absence of a disease (i.e. malnutrition) in a patient depending on its accuracy (sensitivity, specificity of the test, i.e. malnutrition screening tool) in a given population (i.e. older adults 65+) for a given separator variable (i.e. screening score) and positivity criterion (i.e. screening score cut-off). It has potential value to decision makers in populations where the decision pathways may change based on the test results.

The following Bayes formula is used to compute the probability that a patient has the disease given a positive test result.

$$P[D|T^+] = \frac{P[T^+|D] * P[D]}{P[T^+]}$$

$$P[T^+] = (P[T^+|D] * P[D]) + (P[T^+|No\ D]) * P[No\ D])$$

$$P[D|T^+] = \frac{P[T^+|D] * P[D]}{(P[T^+|D] * P[D]) + (P[T^+|No\ D]) * (1 - P[D])}$$

$$P[D|T^+] = \frac{Sensitivity * Prevalence}{(Sensitivity * Prevalence) + (1 - Specificity) * (1 - Prevalence)}$$

By inverting the decision tree in applying Bayes theorem, as presented in this thesis (see Results, Fig. 4.4 and Discussion, section 5.3), the sensitivity and specificity of the malnutrition screening tool and prior risk of malnutrition are incorporated in a decision analytic model to estimate the expected outcomes (i.e. cost and effect changes in the hospital and in the community) comparing different malnutrition screening tools.

Importantly, note that the base risk of disease (prevalence) is important when considering the impact of sensitivity versus specificity and the separator criterion in applying Bayes theorem on health effect, care, cost and cost-effectiveness. Ceteris Paribus (other things being equal), for rare diseases or conditions at a population level, specificity becomes more important when considering unnecessary care and its costs and side effects. When the prevalence of a disease is very high, then sensitivity becomes more critical in having appropriate treatment if a diagnostic test is used. Note, in relation to whether a test should be used, if prevalence of a disease is low enough (i.e. approaches 0) then at a population level it may be better not to test or treat. However, it is also the case that if prevalence of a condition is high enough, i.e. probability approaches 1, then the best option may be not to test and always treat. These considerations are kept in mind in relation to malnutrition screening and diagnosis policies in section 5.3, given the high malnutrition prevalence observed in over 65 patients presenting in hospital.

4 RESULTS

4.1 Clinical study re-analysis for robust health economic evaluation

4.1.1 Clinical analysis of standardised odds ratios

While Charlton and colleagues (2013) use relative risk (RR) to analyse in-hospital mortality/ increased level of care on discharge, comparing between malnourished or patients at risk of malnutrition with well-nourished older patients, Eckermann et al. (2011) show RR is inconsistent in estimating absolute risk difference with alternate framing of binary outcomes, where necessary for health economic analysis. Absolute risk difference and standardisation of such differences change with alternative framing of binary outcomes when estimated with RR. Odds ratios (OR) provide a solution to this framing and analysis selection problem for binary outcomes, enabling consistent estimation of absolute risk difference and standardisation of such differences in informing net clinical benefit and economic analysis across forms of evidence synthesis and translation (Eckermann et al. 2009, 2011, Eckermann 2017).

Consequently, OR was used instead of RR for the combined binary outcome of mortality/discharge to higher level of care in estimating malnutrition-based effects for the health economic analysis. Odds of mortality/discharge to higher level of care were determined for each of the malnourished, at risk and well-nourished categories for ortho-paedic and respiratory patient groups, as shown in Table 4.1. OR were calculated comparing malnourished versus well-nourished, at risk versus well-nourished and malnourished versus nutritionally at risk patients for the orthopaedic and respiratory group. However, since no patient in the falls group died or had an increased level of care at discharge, no OR could be calculated for falls alone. Nevertheless, falls patients (n=66) together with the orthopaedic (n=314) and respiratory (n= 101) patients were included in the overall analysis in calculating OR and RR (for comparisons with Charlton's 2013 analysis), where probabilities were weighted by their respective patient proportions. The weighted overall OR for deaths or higher level of care (standardising proportions across falls, respiratory and orthopaedic groups) for malnourished versus well-nourished patients was 5.04 and RR was 3.35. The weighted OR for at risk versus well-nourished patients was 3.32 and RR was 2.58.

Table 4.1 Probabilities and odds of mortality or discharge to higher level of care reported for malnourished (MN), at risk (AR) and well-nourished (WN) patients within each MDC and odds ratios (OR) comparing MN or AR of malnutrition versus WN and MN versus AR patients

MDC	Nutritional status	Probability (95% CI)	Odds	OR Mortality/increased care		
		Mortality/increased care	Mortality/increased care	MN vs WN	AR vs WN	MN vs AR
Orthopaedics	Malnourished	0.360 (0.260, 0.461)	0.564	2.98		1.33
(n = 314)	At risk	0.298 (0.231, 0.365)	0.425		2.25	
	Well-nourished	0.159 (0.056, 0.263)	0.189			
Respiratory	Malnourished	0.436 (0.282, 0.590)	0.773	6.95		1.33
(n = 101)	At risk	0.367 (0.235, 0.500)	0.581		5.23	
	Well-nourished	0.100 (0, 0.286)	0.111			
Falls	Malnourished	0.667 (0.489, 0.844)	2.000	-		3.50
(n = 66)	At risk	0.364 (0.200, 0.528)	0.571		-	
	Well-nourished	0.000	0.000			
Weighted total	Malnourished	0.418 (0.341, 0.496)	0.719			
(n = 481)	At risk	0.322 (0.265, 0.378)	0.474	5.04	3.32	1.52
	Well-nourished	0.125 (0.044, 0.206)	0.143	(RR = 3.35)	(RR = 2.58)	(RR = 1.30)
Total population (n = 774)						
Charlton et al. (2013)			*Binary logistic regression*	*RR = 3.57*	*RR = 2.46*	*not reported*

MDC (Major Disease Classification), malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment), RR (Relative risk)

Note that with OR as a symmetric metric, Table 4.2 shows that changing the framing of the binary outcome to survival without an increase in level of care, the OR for malnourished versus well-nourished is 0.20 (simply the reciprocal of 5.04 for mortality or discharge to higher level of care). Similarly, the OR for at risk versus well-nourished is 3.32 with mortality or increased level of care versus 0.30 for survival with no change in care level.

In contrast, alternate framing of binary outcomes leads to inconsistent estimates with the non-symmetric RR. For example, Table 4.2 shows that the RR of survival without increase in level of care for malnourished versus well-nourished is 0.66, not the reciprocal of 3.35 for mortality/discharge to higher level of care. Similarly with at risk versus well-nourished, the RR of survival is 0.78 compared to 2.58 with mortality or discharge to higher level of care. In general, RR is demonstrated to be inconsistent in estimating relative treatment effect with alternate framing of binary outcomes, unlike symmetric OR where the extent and direction are consistent and simply and intuitively represent the reciprocal with alternate framing following Eckermann et al. (2009, 2011).

Nevertheless, the standardised MDC-adjusted RR analysis of combined mortality or discharge to higher level of care provides similar results with the three homogenous MDC groups as they had with combining many heterogeneous groups in their previous binary logistic regression analysis Charlton et al. (2013). That is, standardised RR of 3.35 and 2.58 for malnourished and at risk patients, respectively, compared to their well-nourished counter-parts, in the combined orthopaedic, respiratory and falls groups are comparable to the RR's calculated from Charlton's study, providing mutual support and confidence across these analyses produced with different methods. In Charlton's larger while more heterogeneous population analysed using logistic regression the malnourished were 3.57 times ($p = 0.000$) and at risk 2.46 times ($p=0.003$) more likely than the well-nourished to die or have increased level of care.

Table 4.2 Probabilities and odds of survival with no increase in level of care reported for malnourished (MN), at risk (AR) and well-nourished (WN) patients within each MDC and odds ratios (OR) comparing MN or AR of malnutrition versus WN and MN versus AR patients

MDC	Nutritional Status	Probability (95% CI) Survival no increase care level	Odds Survival no increase care	OR Survival no increase in care level MN vs WN	AR vs WN	MN vs AR
Orthopaedics	Malnourished	0.640 (0.539, 0.740)	1.774	0.34		0.75
(n = 314)	At risk	0.702 (0.635, 0.769)	2.353		0.45	
	Well-nourished	0.841 (0.737, 0.944)	5.286			
Respiratory	Malnourished	0.564 (0.410, 0.718)	1.294	0.14		0.75
(n = 101)	At risk	0.633 (0.500, 0.765)	1.722		0.19	
	Well-nourished	0.900 (0.714, 1.000)	9.000			
Falls	Malnourished	0.333 (0.156, 0.511)	0.500	-		0.29
(n = 66)	At risk	0.636 (0.472, 0.800)	1.750		-	
	Well-nourished	1.000	-			
Weighted total	Malnourished	0.582 (0.504, 0.659)	1.391			
(n = 481)	At risk	0.678 (0.622, 0.735)	2.108	0.20	0.30	0.66
	Well-nourished	0.875 (0.794, 0.956)	7.009	(RR = 0.66)	(RR = 0.78)	(RR = 0.86)

MDC (Major Disease Classification), malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment), RR (Relative risk)

The following tables from the current study show the decomposition of the composite endpoint (mortality/discharge to higher level of care) into component endpoints (in-hospital mortality and survival with increased level of care). That is, odds of in-hospital mortality (Table 4.3) and odds of survival with increased level of care (Table 4.4) alone were calculated for each of the malnourished, at risk and well-nourished orthopaedic, respiratory and falls patient group.

OR are then able to be calculated comparing malnourished versus well-nourished, at risk versus well-nourished, and malnourished versus nutritionally at risk patients. Since none of the six well-nourished patients in the falls population died, no OR or RR could be calculated for falls when comparing the malnourished or at risk with the well-nourished group. In the weighted population of 481 orthopaedic, respiratory and falls patients, the OR of an in-hospital death within 12 months for the malnourished patient group was 4.95 (RR 4.13), and 2.83 (RR 2.59) for those at risk of malnutrition, compared to the well-nourished older patient group; comparable to Charlton's study as shown in Table 4.3. The OR of survival with increased care within 12 months for malnourished older patients was 3.30 (RR 2.82) and 2.93 (RR 2.57) for older patients at risk of malnutrition compared to the well-nourished (Table 4.4).

The composite 'mortality/discharge to higher level of care' outcome (Table 4.1) shows that nutritional status, i.e. being malnourished versus well-nourished, had varying levels of increasing the absolute probability of dying or going to higher level care. In the orthopaedic patient group the probability of dying or going to higher level care increased by 0.201 (0.360 vs. 0.159), in the falls population by 0.667 (0.667 vs. 0), while in the respiratory population by 0.336 (0.436 vs 0.100). Naturally, these probabilities are also consistently estimated for the reciprocal 'survival with no increase in level of care' (Table 4.2), given the symmetric property of the OR metric. Such analysis points to malnutrition being particularly important in falls patients, a finding not unexpected given the general care needs of falls patients within and beyond admission and malnutrition status having a close relationship with/proxying for, care needs and whether they are being met.

Table 4.3 Probabilities and odds of in-hospital mortality reported for malnourished (MN), at risk (AR) and well-nourished (WN) patients within each MDC and odds ratios (OR) comparing MN or AR of malnutrition versus WN and MN versus AR patients

MDC	Nutritional status	Probability (95% CI) Mortality	Odds Mortality	OR Mortality MN vs WN	AR vs WN	MN vs AR
Orthopaedics	Malnourished	0.151 (0.076, 0.226)	0.178	3.74		1.34
(n = 314)	At risk	0.117 (0.070, 0.164)	0.132		2.78	
	Well-nourished	0.045 (0, 0.104)	0.048			
Respiratory	Malnourished	0.308 (0.165, 0.451)	0.444	4.00		2.28
(n = 101)	At risk	0.163 (0.062, 0.265)	0.195		1.76	
	Well-nourished	0.100 (0, 0.286)	0.111			
Falls	Malnourished	0.333 (0.156, 0.511)	0.500	-		2.80
(n = 66)	At risk	0.152 (0.029, 0.274)	0.179		-	
	Well-nourished	0.000	0.000			
Weighted total	Malnourished	0.209 (0.145, 0.273)	0.264			
(n = 481)	At risk	0.131 (0.091, 0.172)	0.151	4.95	2.83	1.75
	Well-nourished	0.051 (0, 0.104)	0.053	(RR = 4.13)	(RR = 2.59)	(RR = 1.59)
Total study population (n = 774)		*Unadjusted survival analysis*		*3.68*	*1.89*	*not reported*
Charlton et al. (2013)	*Relative risk (RR)*	*Adjusted survival analysis*		*3.55*	*1.79*	*not reported*

MDC (Major Disease Classification), malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment)

Table 4.4 Probabilities and odds of increased level of care without mortality reported for malnourished (MN), at risk (AR) and well-nourished (WN) patients within each MDC and odds ratios (OR) comparing MN or AR of malnutrition versus WN and MN versus AR patients

MDC	Nutritional status	Probability (95% CI)	Odds	OR Increase care			Probability Survival no change (**Table 4.2**) = 1 - P(Mortality or
		Increased care	Increased care	MN vs WN	AR vs WN	MN vs AR	Increased care)
Orthopaedics	Malnourished	0.209 (0.124, 0.294)	0.265	2.06		1.20	0.640
(n = 314)	At risk	0.181 (0.125, 0.238)	0.221		1.73		0.702
	Well-nourished	0.114 (0.024, 0.203)	0.128				0.841
Respiratory	Malnourished	0.128 (0.025, 0.232)	0.147	-		0.57	0.564
(n = 101)	At risk	0.204 (0.093, 0.315)	0.256		-		0.633
	Well-nourished	0.000	0.000				0.900
Falls	Malnourished	0.333 (0.156, 0.511)	0.500	-		1.86	0.333
(n = 66)	At risk	0.212 (0.073, 0.352)	0.269		-		0.636
	Well-nourished	0.000	0.000				1.000
Weighted total	Malnourished	0.209 (0.145, 0.273)	0.265				0.586
(n = 481)	At risk	0.190 (0.143, 0.238)	0.235	3.30	2.93	1.13	0.683
	Well-nourished	0.074 (0.010, 0.138)	0.080	(RR = 2.82)	(RR = 2.57)	(RR = 1.10)	0.878

MDC (Major Disease Classification), malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment), RR (Relative risk)

In general, for the composite outcome of mortality/discharge to higher level of care (Table 4.1), which combines 'mortality' (Table 4.3) and 'increased level of care with survival' (Table 4.4)), within each MDC there was a higher probability for malnourished compared to at risk and well-nourished patients across all three MDC categories. Correspondingly, the well-nourished population in each MDC category always had the lowest probability for the composite outcome ('mortality/discharge to higher level of care') and the single outcomes ('in-hospital mortality' and 'survival with increased level of care'). Indeed, none of the well-nourished older patients in the falls group died in hospital or had increased level of care after discharge; they had all survived without an increase in their level of care.

However, in considering the components of the composite outcomes in isolation, the respiratory patient population had a higher probability of an increased level of care amongst survivors (0.204) when they were at risk of malnutrition compared to being malnourished (0.128), while for the orthopaedic and falls MDCs this was higher in the malnourished patient group (Table 4.4) as expected. Furthermore, it is apparent from the malnourished respiratory patients dying or having increased level of care (0.436, Table 4.1), that a higher proportion died in hospital (0.308, Table 4.3) than survived with increased level of care (0.128, Table 4.4) compared to malnourished orthopaedic patients (0.151 vs 0.209). In the malnourished falls group, the same proportion of patients died (0.333) as received increased level of care (0.333). The combined probability of mortality or increased level of care when malnourished was highest for falls patients (0.667) compared to orthopaedic (0.360) and respiratory (0.436) patients. Importantly, combining 12-month mortality and higher level of care endpoints addresses the masking of apparent nutrition state impacts on higher level care in the respiratory patient population, considering higher level care in isolation (Table 4.4), i.e. the endpoint of higher level care without mortality. That is, while for respiratory patients the probability of higher level care for survivors is higher in the at risk compared to malnourished population (0.204 vs. 0.128, Table 4.4) this masks the real direction when appropriately considering probabilities by malnutrition status for higher level care in conjunction with mortality (0.367 vs. 0.436) or equivalently survival without higher level care (0.633 vs. 0.564 in Table 4.2).

For analyses by malnutrition status across MDCs, to allow feasible standardisation, the nutritionally at risk patient group was combined with the well-nourished patient group, denoted as 'not malnourished', in order to compare with the 'malnourished' patient group. This nutritional status grouping has several advantages as it allows for:

1) A more robust statistical analysis due to greater patient numbers in the not malnourished comparison group;

2) Consistently applying OR in the decision tree model with malnourished or not malnourished treated as a binary outcome and;

3) Natural extension of analysis with binary outcomes through to consideration of diagnostic value of nutrition screening.

In relation to (1), comparing malnourished with not malnourished (at risk and well-nourished) patients enabled analysis of patients within each MDC for orthopaedic, respiratory and falls conditions. A combined analysis across MDC standardises probabilities applying the same population weights for malnourished and not malnourished across the three MDC's. That is, standardisation across MDC's requires that the same proportions are used for each MDC. These proportions are estimated by the proportion of population in each MDC across all the nutritional states. This enables estimation of the standardised (weighted) effects of nutritional status across MDCs. When comparing malnourished versus not malnourished patients across the three MDCs, the malnourished compared to the not malnourished older adults have an OR of 2.00 of dying in hospital (Table 4.5). Malnourished falls patients had the highest OR (3.40) of dying in hospital within 12 months of follow-up, compared to the not malnourished group. Patients with orthopaedic and respiratory conditions had an OR of 1.56 and 2.47, respectively, for in-hospital mortality.

Table 4.5 Probabilities and odds of in-hospital mortality and survival with increased level of care reported for malnourished (MN) and not malnourished (NM) patients within each MDC and odds ratios (OR) comparing MN versus NM patients

MDC	Nutritional status	Probability (95% CI) Mortality	Odds	OR MN vs NM	Probability (95% CI) Survival increased care	Odds	OR MN vs NM
Orthopaedics	Malnourished	0.151 (0.076, 0.226)	0.178	1.56	0.209 (0.124, 0.294)	0.265	1.32
(n = 314)	Not malnourished	0.102 (0.063, 0.142)	0.114		0.167 (0.119, 0.216)	0.201	
Respiratory	Malnourished	0.308 (0.165, 0.451)	0.444	2.47	0.128 (0.025, 0.232)	0.147	0.72
(n = 101)	Not malnourished	0.153 (0.062, 0.243)	0.180		0.169 (0.075, 0.264)	0.204	
Falls	Malnourished	0.333 (0.156, 0.511)	0.500	3.40	0.333 (0.156, 0.511)	0.500	2.29
(n = 66)	Not malnourished	0.128 (0.023, 0.233)	0.147		0.179 (0.059, 0.300)	0.219	
Weighted total	Malnourished	0.209 (0.145, 0.273)	0.264	2.00	0.209 (0.145, 0.273)	0.265	1.30
(n = 481)	Not malnourished	0.116 (0.082, 0.151)	0.132		0.170 (0.129, 0.210)	0.204	

MDC (Major Disease Classification), malnourished (MNA < 17), at risk of malnutrition & well-nourished (MNA = 17 – 24+), MNA (Mini Nutritional Assessment)

Analogous to the comparison of all three nutritional states with each other, analysis presented in Tables 4.5 and 4.6 for malnourished versus not malnourished shows the decomposition of the appropriate composite endpoint of mortality or higher level of care across the orthopaedic, respiratory and falls population groups. In Table 4.5, for respiratory patients, the OR for the component outcome of survival with increased level of care for those with malnourished versus those considered not malnourished was 0.72, while it was 2.47 for mortality.

The greater probability of deaths in respiratory patients, as with malnourished versus at risk, is likely masking the relationships for higher level of care. Patients are dying rather than requiring higher level of care. This is reflected in Table 4.6 where the OR for combined death or higher level of care is 1.63. The OR is nevertheless greatest in falls patients, with an OR of 4.50, with the implication that they have most to benefit of these patient populations presenting in hospital when they are not malnourished. As noted above, a finding not unexpected given the general care needs of falls patients within and beyond admission and malnutrition status having a close relationship with / proxy for, care needs and whether they are being met. This more generally points to the particular need for models of care such as RED in aged populations presenting in hospital with high prevalence of malnutrition to improve nutrition within and beyond admission and associated care needs (see conservative base case modelled analysis section 4.2.6) and their potential to both improve survival and reduce need for higher level care (see sensitivity analyses in section 4.2.7), and resulting policy implications for health and aged care systems considered in chapter 5.

Table 4.6 Probabilities and odds of mortality or discharge to higher level of care reported for malnourished (MN) and not malnourished (NM) patients within each MDC and odds ratios (OR) comparing MN versus NM patients

MDC	Nutritional status	Probability (95% CI) Mortality/ increased care	Odds	OR MN vs NM	Probability (95% CI) Survival no change	Odds	OR MN vs NM
Orthopaedics	Malnourished	0.360 (0.260, 0.461)	0.564	1.53	0.640 (0.539, 0.740)	1.774	0.66
(n = 314)	Not malnourished	0.270 (0.212, 0.328)	0.369		0.730 (0.672, 0.788)	2.707	
Respiratory	Malnourished	0.436 (0.282, 0.590)	0.773	1.63	0.564 (0.410, 0.718)	1.294	0.61
(n = 101)	Not malnourished	0.322 (0.059, 0.237)	0.475		0.678 (0.763, 0.941)	2.105	
Falls	Malnourished	0.667 (0.489, 0.844)	2.000	4.50	0.333 (0.156, 0.511)	0.500	0.22
(n = 66)	Not malnourished	0.308 (0.023, 0.233)	0.444		0.692 (0.767, 0.977)	2.250	
Weighted total	Malnourished	0.418 (0.341, 0.496)	0.719	1.80	0.582 (0.504, 0.659)	1.391	0.56
(n = 481)	Not malnourished	0.286 (0.179, 0.270)	0.400		0.714 (0.730, 0.821)	2.497	

MDC (Major Disease Classification), malnourished (MNA < 17), at risk of malnutrition & well-nourished (MNA = 17 – 24+), MNA (Mini Nutritional Assessment)

4.1.2 Kaplan-Meier survival analysis

The standardised OR analyses are further supported with survival analysis using Kaplan-Meier survival curves over time and which allows additional comparison to the clinically focussed Cox proportional hazards regression survival analysis of Charlton et al (2013). Charlton et al. (2013) performed survival analysis for the outcome of in-hospital mortality (including hospital mortality covering readmissions over the 12 month follow-up from date of index admission) for 774 patients across their five defined MDC groupings, of which three were homogenous and two relatively heterogeneous. Their analysis presented an adjusted Cox proportional hazards regression model with time to death as the dependent variable, hospital related deaths as an event, and allowed for covariates (independent variables) of MNA category (with 'well-nourished' as reference category), MDC (with 'other' as reference category) and gender (with 'female' as reference category). In the present study, the aim was to robustly inform policy and health economic analysis (jointly satisfying comparability and coverage principles) by comparison of survival (using OR and Kaplan-Meier curves) that had been restricted to patients within the three homogeneous MDCs (i.e. orthopaedics, respiratory and falls conditions). Hence, data for 481 patients is considered across MNA nutritional status categories. These analyses are summarised in Fig. 4.1 showing Kaplan-Meier curves of all three MNA categories and Fig. 4.2 showing survival curves of the malnourished versus the not malnourished patient group. In each case, the Kaplan-Meier curve comparability is supported by standardising mortality rates with a common proportion of patients in each of the MDCs (determined from the whole population) when combining mortality rates across MDCs.

The standardised total population Kaplan-Meier curve combining MDCs adjust for differences in proportion of patients across MDCs. That is, standardised KM curve across MDCs is achieved by attaching relevant population weights to KM curves and their probabilities at each point. Graphically, and as expected, this shows a lower survival curve for the malnourished patients compared to the at risk patients ($p = 0.001$) or to the well-nourished patients ($p = 0.003$, Fig. 4.1). While the direction of treatment effect on survival between the survival curves for the nutritionally at risk and the well-nourished patient group is in the expected direction, there is no statistical difference at 12 months ($p = 0.167$); reflecting the small proportion and the low number of well-nourished older patients (13.3%, $n = 64$, see Table 3.3).

The Kaplan-Meier estimates generally agree with the findings from Charlton's survival analysis where there was a significant difference between the malnourished and well-nourished group but not between the at risk and well-nourished patient groups. The analysis of more homogenous MDC groupings also shows a difference in survival time between malnourished patients and those at risk of malnutrition ($p = 0.001$); a finding not evident in the more heterogeneous MDC groupings reported by Charlton et al. (2013). Combining the nutritionally at risk with the well-nourished to compare malnourished and not malnourished patient groups increases the statistical while not the clinical significance of the reduction in survival with malnourished patients ($p = 0.0001$; Fig. 4.2).

Fig. 4.1 Kaplan-Meier survival curves showing the malnourished (MN), at risk (AR) and well-nourished (WN) patient groups over 12 months of follow-up

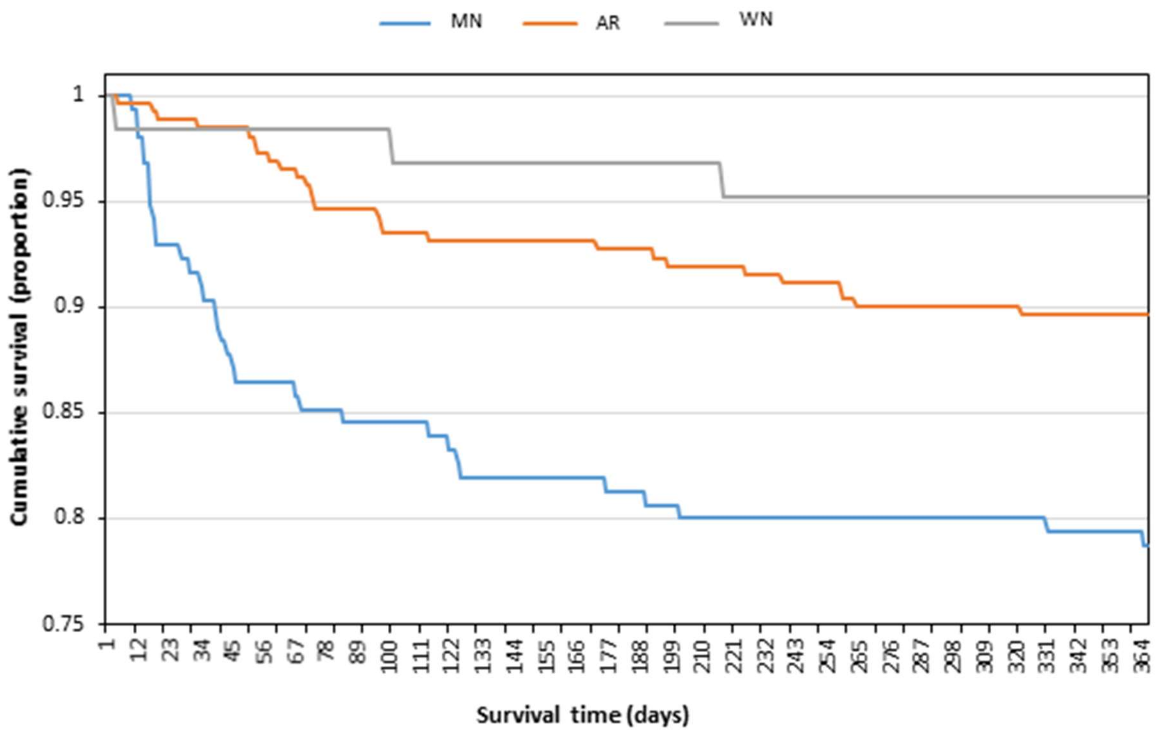
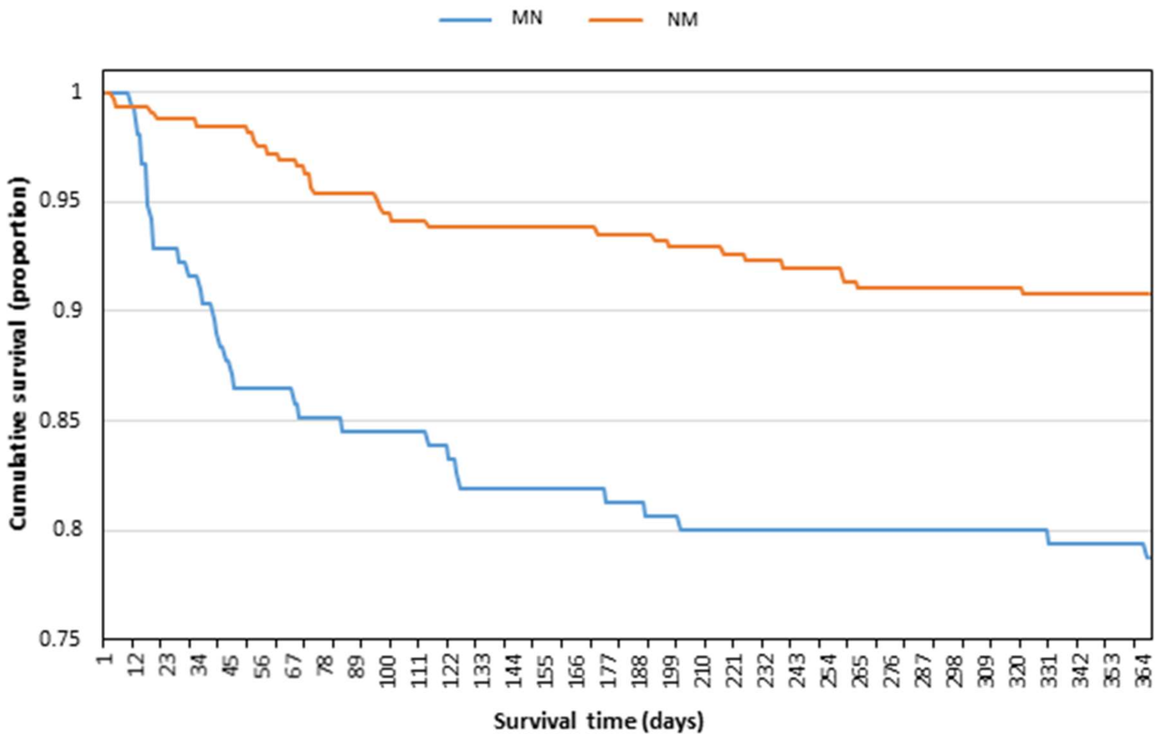


Fig. 4.2 Kaplan-Meier survival curves showing the malnourished (MN) and not malnourished (NM, combined at-risk and well-nourished) patient groups over 12 months of follow-up



4.2 Cost-effectiveness modelling of strategies addressing hospital malnutrition

4.2.1 Natural history model of nutrition care practice for older acute care patients

To allow later consideration of the incremental cost and effect impact expected with an alternative model of care for patients diagnosed as having or being at risk of malnutrition, a model of the natural history of geriatric usual care in the Australian acute hospital setting was first developed (Fig. 4.3). In Charlton's study, all older acute hospital patients were assessed by a dietitian using the 18-item MNA, establishing the prevalence of patients being malnourished, nutritionally at risk and well-nourished (Charlton et al. 2013). The 18-item MNA consists of a nutrition screening and assessment section. In actual practice, there are considerations in relation to whether: (i) an over 65 patient is screened for malnutrition upon admission, (ii) a patient screened as being malnourished is referred to a dietitian for a full nutritional assessment, (iii) a malnourished patient is referred early enough or resources are available to allow dietary treatment while in hospital and (iv) choice of therapy reflects practice variation or alternative decisions among acute hospital settings or patient populations rather than necessarily the best practice pathways recommended. There are no written formal protocols or treatment care pathways for management of inpatients identified as malnourished.

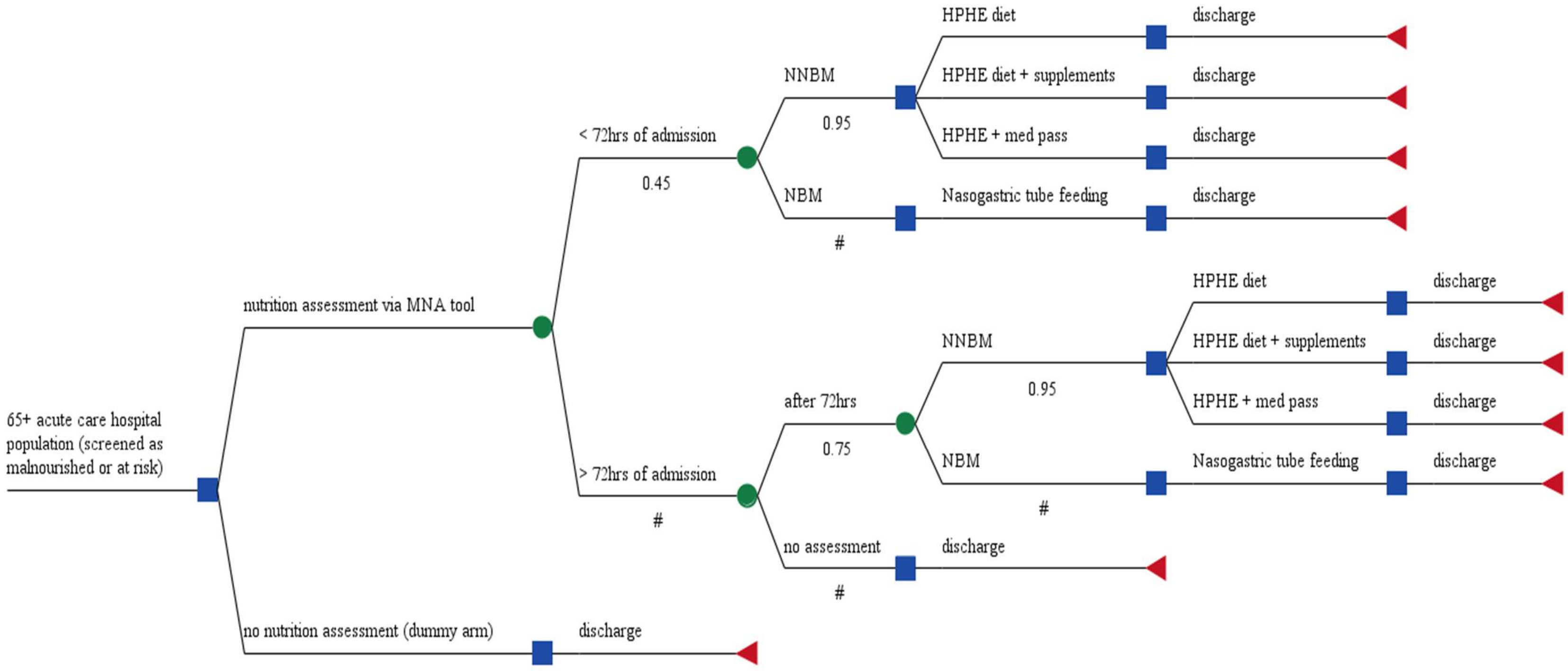
For all patients 65 years and older, it is now the protocol within the hospital network of the Illawarra and Shoalhaven Local Health District to undergo an initial nutrition screening by nursing staff at admission using the Malnutrition Screening Tool (MST) or the MNA-SF (Fig. 4.4). Malnutrition identification and treatment take place alongside the medical treatment for the patient's underlying disease. The malnutrition screening results in two categories – at risk (includes malnourished) or not at risk of malnutrition. For all patients identified as at risk of malnutrition, a referral to a dietitian is made for a full nutrition assessment, aimed to be conducted within 72 hours of hospital admission (Fig. 4.3). However, whether the referral leads to being seen in that timeframe is subject to the dietitian's workload. The full nutrition assessment classifies patients as in one of three MNA categories; malnourished, at risk of malnutrition or well-nourished.

The natural history model in Fig. 4.3 reflects current usual in-hospital care and variations across patient pathways and in practice under scarcity of resources, where not all older at risk patients can be seen by a dietitian for a full nutrition assessment. This incorporates probabilities on whether the patients are assessed early enough (i.e. within 72 hours of index admission) reflecting given staffing resources. In the study hospital in 2009/10, 45% of patients at risk were estimated to receive a nutrition assessment within 72 hours of index admission based on clinically informed estimates. For the remaining 55% of patients, 75% of patients had delayed nutrition assessment to after 72 hours, while 25% of patients ended up not having an assessment.

For optimal dietary care of patients screened to potentially have malnutrition, dietitians need to be available to allow early individualised diagnosis and care in hospital rather than variations in applying best practice depending on access. Once diagnosed using a full nutritional assessment, malnourished and at risk older patients are treated with one of the four dietary options which are standard across hospitals in NSW. The choice of dietary treatment reflects potential for further practice variation among dietitians. Dietitians make individualised therapy decisions for malnourished older patients based on the patient's current intake and the likelihood the patient has of drinking the volume or supplements provided. Dietitians' recommendations may involve a change to diet provided, use of nutritional supplements, supplementary feeding (via a nasogastric tube) or other mechanism as determined by the dietitian at the time. Patients who are able to eat are allocated to one of three treatment options: 1) high protein high energy (HPHE) diet, 2) HPHE diet plus commercial supplements, 3) HPHE diet plus med pass (Medication Pass Nutrition Supplement Program, i.e. medications dispensed in a nutrition supplement and given three times per by nursing staff). Those with nil by mouth (NBM) or limited eating abilities and malnutrition are expected to receive nasogastric tube feeding authorised by the clinician (Fig. 4.3).

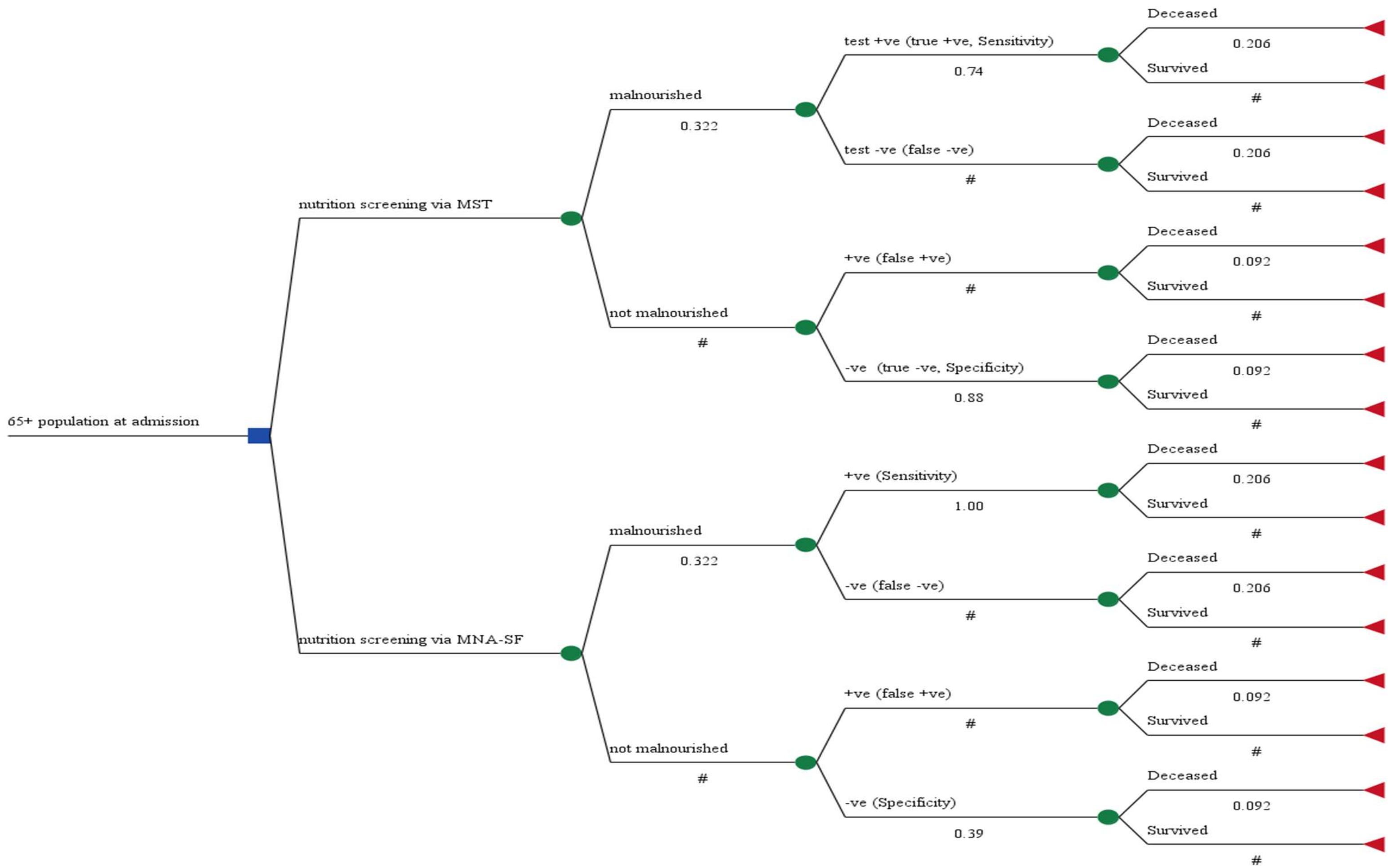
For each of the dietary treatment options, the patient's dietary intake is re-assessed after three days, in order to calculate their current intake and compare it to the calculated requirements usually energy and protein. If patients' dietary intake is sufficient, they continue their dietary treatment until they are discharged from hospital. Where the patient's intake is insufficient, a new dietary component is added to the HPHE diet (e.g. HPHE diet plus supplements or plus med pass) and the dietary intake measured after three days. Those who receive NG tube feeding are reviewed daily, and the tube is removed 90% of the time before they are discharged.

Fig. 4.3 Natural history model tree – nutrition care practice for older patients in the acute hospital



NNBM – Not Nil by Mouth
NBM – Nil by Mouth
HPHE – high protein high energy
med pass – Medication Pass Nutrition Supplement Program (i.e. medications dispensed in nutrition supplement)

Fig. 4.4 Inverted decision tree - current nutrition screening practice in usual care for older acute hospital patients



MST – Malnutrition Screening Tool
MNA-SF – Mini Nutritional Assessment-Short Form

Older malnourished patients who receive their full nutrition assessment after 72 hours of admission follow the same, but delayed dietary treatment pathways compared to those assessed within 72 hours of admission. Nutritionally at risk patients would either be started on the same pathways or not started and monitored.

In ensuing sections, this practice for older acute hospital patients is compared with an alternative model of care (RED care model, section 4.2.2) to treat malnourished ill older patients, to estimate incremental costs and effects relative to usual care.

4.2.2 Direct costs of implementing the RED care model

The wage rate of the discharge planner including on-costs is the key variable for estimating direct costs of RED. The discharge planner at the study hospital in 2009/10 covered four acute care wards and an estimated 110 patients per each 38-hour (2280 minutes) work week. Hence the discharge planner spent on average 20.7 minutes per patient (2280 minutes/week divided by 110 patients/week). The discharge nurse advocate in the RED study (Jack et al. 2009) in total spent 87.5 minutes on average per patient in total; an average of 42.5 minutes collecting and packaging the patient information and teaching the discharge plan to the patient and an average of 45 minutes reviewing patient records, contacting interns (three times typically), communicating with the medical team and preparing the discharge plan. Thus, the discharge nurse advocate with the RED care model spent 66.8 minutes longer per patient coordinating care compared to that of the discharge planner in the usual practice of care study over the 2009/10 period (Charlton et al. 2013).

The discharge planners at the study hospital in 2009/10 were employed as either a registered nurse (8^{th} year and thereafter, AUD 1,382.50 per 38 hour week) or as a clinical nurse consultant (Grade 2 and 2^{nd} year, AUD 1,835.40 per 38 hour week) with 20% on-costs (Nurses Award 2010). To estimate discharge planner base case costs, a weighted average of wage rates and weekly salary levels for registered nurses (50%) and clinical nurse consultants (50%) was applied, resulting in an average weekly wage rate of AUD 1,930.74 including on-costs, or AUD 50.81 per hour. Hence, implementing RED instead of usual care suggests an average of 66.8 additional minutes and results in direct additional costs of the RED care model or AUD 56.57 per patient. That is, it is expected to cost an additional AUD 56.57 for the discharge planner to spend 87.5 minutes per patient with RED, rather than 20.7 minutes with usual care.

4.2.3 RED treatment effect applied to hospital utilisation

The RED study (Jack et al. 2009) aimed to reduce hospital utilisation through systematic coordination by the discharge nurse advocate. The RED care model showed a significantly lower rate of rehospitalisations (readmissions and ED visits) at 30 days (0.314 with RED compared to 0.451 with usual care, with a relative risk reduction of 30.4%, p=0.009). Readmission rates up to 30 days post separation from index admission were 0.207 in the usual care group compared to 0.149 in the RED intervention group, a relative risk reduction of 28.0% (0.149/0.207 = 0.720).

The 30-day and 12-month readmission rates for the malnourished, at risk and well-nourished older patient groups in the acute Australian hospital setting are shown in Table 4.7. The hospital readmissions were recorded only for the hospital of index admission. Applying the treatment effect from the RED care model to the 30-day readmission or overall hospital utilisation rates of the malnourished study population reduces the 30-day readmission rate from 0.123 to 0.089 (with 28.0% reduction) or to 0.086 (with 30.4% reduction).

Of the 155 malnourished ill older patients, 98 patients (63.2%) had only an index admission, while 57 patients (36.8%) had more than one admission (index admission plus readmission/s) in the 12 month follow-up period, and 91 readmissions in total at 12 months. Hence, in the malnourished study population, the readmission rate at 12 months post index admission was 0.587 (91/155) while the rate at 30 days was 0.123 (19/155). Amongst the 57 patients who were readmitted in the period up to 12 months, 64.9% (37/57) had one readmission, 21% (12/57) had two readmissions, 8.8% (5/57) had three readmissions and 5.3% (3/57) had five readmissions (no patients had four or six or more readmissions).

In at risk and well-nourished populations, 58.8% (154/262) and 51.6% (33/64), respectively, had only an index admission, while 41.2% (108/262) and 48.4% (31/64) had more than one admission in the 12 month follow-up period (Table 4.7). Amongst the 108 at risk patients readmitted, 54.6% (59/108) had one readmission, 26.9% (29/108) had two readmissions,

Table 4.7 Applying the RED treatment effect on 30-day and 12-month hospital readmissions or overall hospital utilisation to the Australian acute care hospital setting

Usual care AUS	**Malnourished patients (n = 155)**	**%**	**At risk patients (n = 262)**	**%**	**Well-nourished patients (n = 64)**	**%**
Patients with 1 admission (index admission)	98	63.2	154	58.8	33	51.6
Patients with ≥1 admission (readmissions)	57	36.8	108	41.2	31	48.4
Readmission timeframe[1]	*1yr*	*30d*	*1yr*	*30d*	*1yr*	*30d*
Readmissions (n)	91	19	211	26	54	6
Readmission rate across all patients	0.587*	0.123	0.805*	0.099	0.844*	0.094
Adjusted with RED Treatment effect						
RED hospital utilisation rate (RR = 0.696)	0.409*	0.086	0.560*	0.069	0.588*	0.065
RED readmission rate (RR = 0.720)	0.422*	0.089	0.579*	0.071	0.608*	0.068

RED (Re-Engineered Discharge), malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment), RR (Relative risk)

[1] In the RED study the authors measured their outcomes (i.e. hospital utilisation) within 30 days of discharge and in Charlton's study 12 months from date of index admission.

* Note relative 12-month hospital readmission rates in usual care to prevent confounding in interpretation of their relative impact by malnutrition status should be considered alongside competing events for mortality and aged care use (see Tables 4.2-4.4), while RED treatment effect should similarly consider their joint impact as in sensitivity analysis in section 4.2.7.

8.3% (9/108) had three readmissions, 3.7% (4/108) had four readmissions, 0.9% (1/108) had five readmissions, 0.9% (1/108) had six readmissions, 1.9% (2/108) had seven readmissions, 0.9% (1/108) had eight readmissions and 1.9% (2/108) had nine readmissions, resulting in 211 readmissions in total. Amongst the 31 readmitted well-nourished patients, 51.6% (16/31) had one readmission, 32.3% (10/31) had two readmissions, 9.7% (3/31) had three readmissions, 3.2% (1/31) had four readmissions and 3.2% (1/31) had five readmissions, resulting in 54 readmissions in total. At risk or well-nourished patients had higher 12-months readmission rates (0.805 and 0.844, respectively) compared to the malnourished patients (0.587).

4.2.4 12-month hospital readmission rates and residential aged care use

In interpreting malnourished older patients not being readmitted to hospital as often as at risk and well-nourished older adults at 12 months, it has to be noted that the malnourished older patients both die at greater rates and utilise residential aged care services earlier (see Table 4.8). Hence, entry to aged care with at risk and well-nourished patients is at a later stage than in the malnourished population, which confounds readmission rates by malnutrition status and use of the RED treatment effect on reductions in rehospitalisation by malnutrition status. More generally, across aged care use and readmissions, improved care coordination with the RED care model within hospital, at discharge and post-discharge can be expected to result in a better health and nutritional status of the older patients and more patients being discharged home instead of going into residential aged care, as sensitivity analyses in section 4.2.7 considers around a conservative base case analysis (section 4.2.6), where modelled benefits of RED are restricted to readmission impacts only.

While at risk and well-nourished older patients have higher hospital readmission rates, this consideration of hospital readmission by malnutrition status is confounded to the extent that in malnourished population there are much higher entry rates to high level aged care and at an earlier stage. This confounding of hospital readmission by aged care use in malnourished populations is also reflected in the 12-month rate of hospital readmission across older patients discharged to high level care depending on whether they were malnourished (0.383), at risk of malnutrition (1.020) or well-nourished (1.667) at index admission, as presented in Table 4.8. Confounding of readmission rates by entry to aged care is also supported by the finding that malnourished patients who entered high level care had a much lower hospital

Table 4.8 Readmission rates up to 12 months follow-up based on the older patient's nutritional status determined by Mini Nutritional Assessment (MNA) and final discharge destination

Older population	**Final discharge destination**	**Change in care level**	**Number readmissions**	**Patient population**	**Readmission rate to 12mths**
Malnourished	Deceased		30	32	0.938
(MNA < 17)	Home		29	52	0.558
	High level care (HLC)		18	47	**0.383**
		Home to HLC	*9*	*16*	*0.563*
		LLC to HLC	*1*	*7*	*0.143*
		No change	*8*	*24*	*0.333*
	Low level care (LLC)		13	21	**0.619**
		Home to LLC	*6*	*9*	*0.667*
		No change	*7*	*12*	*0.583*
At risk of malnutrition	Deceased		36	27	1.333
(MNA = 17 – 23.9)	Home		85	143	0.594
	HLC		51	50	**1.020**
		Home to HLC	*35*	*24*	*1.458*
		LLC to HLC	*10*	*6*	*1.667*
		No change	*6*	*20*	*0.300*
	LLC		37	33	**1.121**
		Home to LLC	*27*	*20*	*1.350*
		No change	*10*	*13*	*0.769*
Well-nourished	Deceased		2	3	0.667
(MNA ≥ 24)	Home		39	49	0.796
	HLC		5	3	**1.667**
		Home to HLC	*1*	*2*	*0.500*
		LLC to HLC	*4*	*1*	*4.000*
	LLC		5	5	**1.000**
		Home to LLC	*2*	*2*	*1.000*
		No change	*2*	*3*	*0.667*

readmission rate compared to those who were discharged to low level care (0.383 vs. 0.619).

Importantly for health economic analysis, where consideration is given to RED impact on nutrition status as well as costs more generally, malnutrition is generally observed to lead to a much higher rate of and earlier entry to high level care. For both these reasons, malnutrition contributes to higher downstream aged care and overall costs despite lower rehospitalisation rates.

4.2.5 RED treatment effect applied to hospital readmission costs

The 12-months cost of inpatient acute care was estimated from linked patient level admission data by MDC category (i.e. 'orthopaedic', 'respiratory' and 'falls' conditions) and their specific DRG cost weight across the nutritional status categories at index admission. This analysis initially focussed on estimating the cost of hospital readmissions (excluding index hospital admission) of malnourished, at risk and well-nourished older patients within a 12-month period from the date of index admission, and then compared this with the incremental costs expected with the RED care model. Based on the RED cost analysis in the US (Jack et al. 2009), RED achieved a net cost offset of USD 412 per patient or 33.9% of the total health care cost of usual care beyond separation from index admission (actual inpatient, emergency department and primary care outpatient visits combined) at 30 days (USD 1,215 per patient), while increasing primary care outpatient visits by 40.9%. The greater overall cost reduction, despite increased primary care use, reflects that it is not just the rate or quantity of hospital readmissions that reduces with RED, but also their complexity. Applying the RED treatment effect, a 30.4% reduction in hospital utilisation is expected, both within 30 days of discharge (index hospitalisation) and up to 12 months after index admission, and overall downstream health care cost reductions of 33.9%.

In Table 4.9, the breakdown of mean DRG weights and costs from hospital admissions, as well as the expected RED adjusted costs for index admissions and hospital readmissions in the malnourished, at risk and well-nourished older patients are shown. The mean DRG weight per malnourished patient from all index admissions was 3.414, which means 3.414 times as complex as the general population's admissions with a DRG weight of 1.000. The mean DRG weight per malnourished patient from hospital readmissions up to 12 months after index hospitalisation was 2.482. The mean readmission costs at the time of study, applying the

2010-11 Round 15 National average cost per weighted separation for acute Australian public hospitals, consequently is AUD 11,449.17 (2.482 multiplied by AUD 4,613.00).

In applying the RED treatment effect across population hospital readmissions or all health system costs, the expected mean readmission DRG weight for malnourished patients reduces to 1.633. That is, multiplying the mean DRG weight per malnourished patient from readmissions from usual care without RED (2.482) by the RED RR for hospital utilisation of 0.696 or that for total health system costs (0.658). Consequently, the expected mean cost for readmissions with RED reduces to AUD 7,968.62 (AUD 11,449.17 multiplied by 0.696) or AUD 7,533.55 (AUD 11,449.17 multiplied by 0.658) and an estimated AUD 3,477.91 (AUD 3,915.62) downstream cost offset per malnourished patient from reduced readmissions expected in applying a RED care model. Incorporating RED into an older (over 65) population in a usual acute care hospital setting in Australia would therefore be expected to save downstream readmission costs in the order of AUD 3,477.91 – 3,915.62 per malnourished patient, reflecting somewhat over three quarters of a DRG case-mix weight (0.754 to 0.849) per patient at a population level. However, the RED care model is expected to reduce readmission costs not just in malnourished patients but across the aged patient population including malnourished, at risk and well-nourished.

Across the malnourished, at risk and well-nourished population, the weighted mean DRG weight per patient and the mean cost of readmissions is 2.861 and AUD 13,196.14 respectively. The mean readmission cost with RED reduces to AUD 9,184.51 with a 30.4% reduction, implying lower costs of readmissions with RED of AUD 4,011.63 (Table 4.9). However, this relative reduction in cost is conservative noting that RED reduced overall health care cost by 33.9% reflecting that, while reducing the rate of rehospitalisation by 30.4%, RED also reduced the complexity of patients and hence their cost per readmission or rehospitalisation.

Table 4.9 Breakdown of mean DRG weights and costs from hospital admissions as well as the expected RED adjusted costs for readmissions in the malnourished, at risk and well-nourished older patients at 12 months after index admission

Usual care AUS	**Malnourished patients (n = 155)**	**At risk patients (n = 262)**	**Well-nourished patients (n = 64)**	**Weighted average Total population (n = 481)**
Mean DRG weight per patient - index admissions	3.414	3.518	2.838	3.394
Mean DRG weight per patient - all inpatient admissions up to 12mths	5.896	6.661	5.462	6.255
Mean DRG weight per patient - readmissions 12mths after index admission	2.482	3.143	2.624	2.861
Readmission rate 12mths	0.587	0.805	0.844	0.740
National cost/DRG weight (AUD), Round 15, 2010-11, acute public hospitals	4,613.00			
NSW cost/DRG weight (AUD)	4,576.00			
Mean cost index admissions (based on National average, AUD)	15,748.30	16,229.65	13,093.57	15,657.26
Mean cost all inpatient admissions (AUD)	27,197.47	30,726.36	25,196.42	28,853.40
Mean cost readmissions (AUD)	11,449.17	14,496.71	12,102.85	13,196.14
Adjusted with RED Treatment effect				
RR Hospital utilisation	0.696			
Expected mean DRG weight from readmissions	1.727	2.188	1.826	1.991
Expected mean cost readmissions (AUD)	7,968.62	10,089.71	8,423.58	9,184.51
Cost reductions expected for readmissions (based on Nat. aver., AUD)	3,480.55	4,407.00	3,679.27	4,011.63
Expected mean DRG weight from index admissions	2.376	2.449	1.975	2.362
Expected mean cost index admissions (AUD)	10,960.82	11,295.84	9,113.12	10,897.45
Cost reductions expected for index admissions (based on Nat. aver., AUD)	4,787.48	4,933.81	3,980.45	4,759.81
Expected mean DRG weight from all inpatient admissions	4.104	4.636	3.802	4.353
Expected mean cost all inpatient admissions (AUD)	18,929.44	21,385.55	17,536.71	20,081.97
Cost reductions expected for all inpatient admissions (based on Nat. aver., AUD)	8,268.03	9,340.81	7,659.71	8,771.43

DRG (Diagnosis Related Group), malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment), RR (Relative risk)

4.2.6 Conservative incremental cost-effectiveness 12-month base case analysis

The base case estimate of incremental costs of RED of AUD 56.57 to the health system by implementing RED into the Australian usual hospital care of all older inpatients (additional time of discharge planner) less the expected readmission cost reduction of AUD 4,011.63 results in an overall net cost savings of AUD 3,955.06 per patient. This base case is conservative in estimating downstream cost savings at 12 months of index admission to the extent that only benefits from RED in terms of cost reductions associated with lower rehospitalisation rates have been included, while the estimate neither includes lower complexity per readmission nor any expected reductions in aged care costs with RED (undertaken in sensitivity analysis in section 4.2.7). The expected costs (excluding index admission) of the base case in geriatric usual care in Australian practice and with the RED care model at each terminal node of the decision tree are listed in Table 4.10.

Fig. 4.5 shows the decision tree for a conservative base case comparing Australian usual care with what could be expected if only the RED treatment effect on downstream hospital costs is applied. Rolling back this base case tree reaffirms a cost saving of AUD 3,950.82 per patient with the RED care model (AUD 9,231.49), while having a higher direct cost of AUD 56.57, relative to usual care in Australia (AUD 13,182.31).

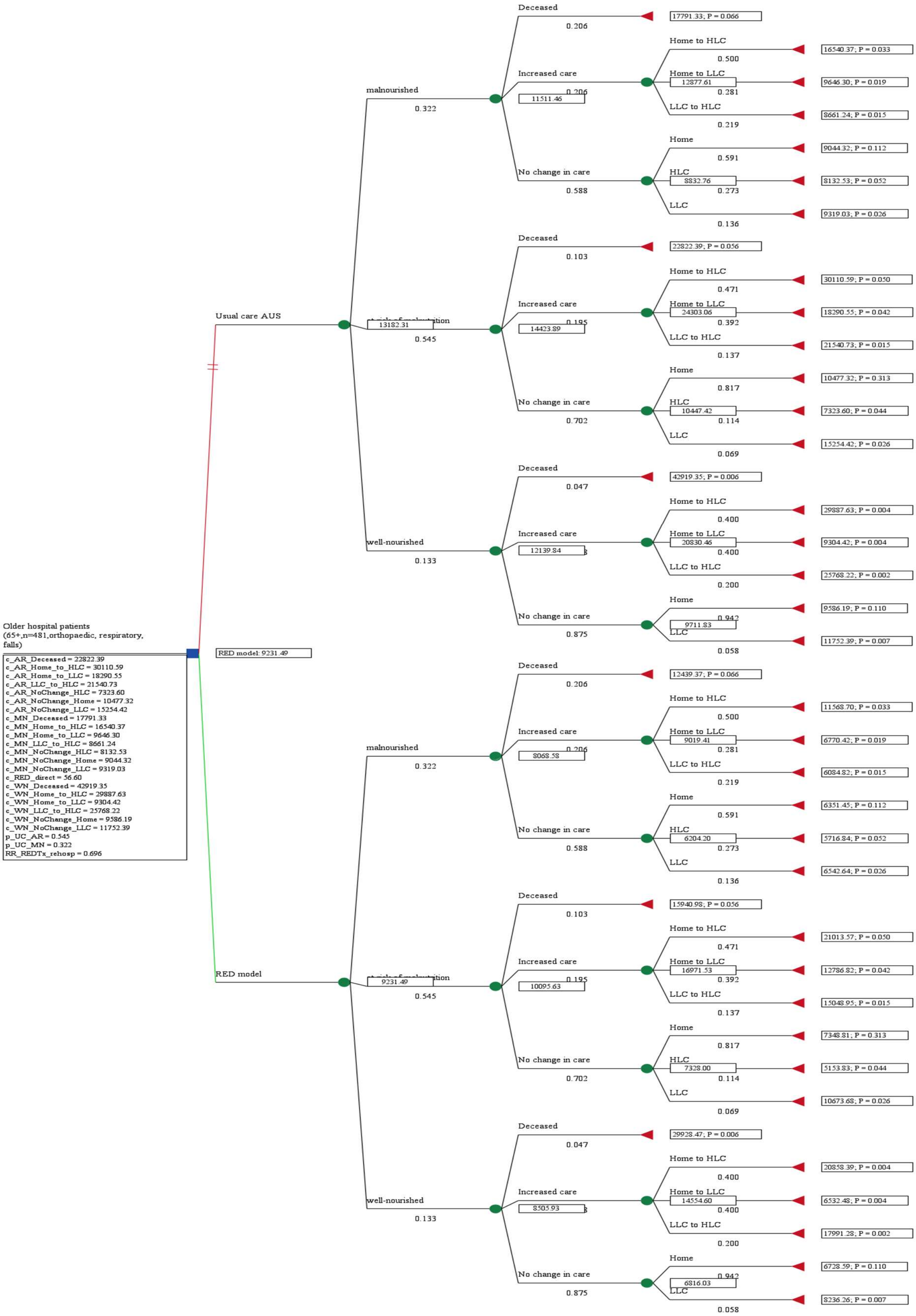
The conservative assumptions of the base case are that the RED care model has:
(1) no effect benefits for survival from malnutrition improvement and
(2) no downstream aged care cost savings.

Table 4.10 12-month base case hospital readmission costs (in AUD) expected with Australian geriatric care practice and with the RED care model at each terminal node in the decision tree

Name	Description	Cost Usual care	Cost RED model
Malnourished patients			
c_MN_Deceased	Cost (c) readmission – malnourished deceased patients	17,791.33	12,439.37
c_MN_Home_to_HLC	Cost readmission – malnourished, discharged from home to high level care (HLC)	16,540.37	11,568.70
c_MN_Home_to_LLC	Cost readmission – malnourished, discharged from home to low level care (LLC)	9,646.30	6,770.42
c_MN_LLC_to_HLC	Cost readmission – malnourished, discharged from low to high level care	8,661.24	6,084.82
c_MN_NoChange_HLC	Cost readmission – malnourished, discharged from high to high level care	8,132.53	5,716.84
c_MN_NoChange_Home	Cost readmission – malnourished, discharged from home to home	9,044.32	6,351.45
c_MN_NoChange_LLC	Cost readmission – malnourished, discharged from low to low level care	9,319.03	6,542.64
At risk patients			
c_AR_Deceased	Cost (c) readmission – at risk deceased patients	22,822.39	15,940.98
c_AR_Home_to_HLC	Cost readmission – at risk, discharged from home to high level care (HLC)	30,110.59	21,013.57
c_AR_Home_to_LLC	Cost readmission – at risk, discharged from home to low level care (LLC)	18,290.55	12,786.82
c_AR_LLC_to_HLC	Cost readmission – at risk, discharged from low to high level care	21,540.73	15,048.95
c_AR_NoChange_HLC	Cost readmission – at risk, discharged from high to high level care	7,323.60	5,153.83
c_AR_NoChange_Home	Cost readmission – at risk, discharged from home to home	10,477.32	7,348.81
c_AR_NoChange_LLC	Cost readmission – at risk, discharged from low to low level	15,254.42	10,673.68
Well-nourished patients			
c_WN_Deceased	Cost (c) readmission – well-nourished deceased patients	42,919.35	29,928.47
c_WN_Home_to_HLC	Cost readmission – well-nourished, discharged from home to high level care (HLC)	29,887.63	20,858.39
c_WN_Home_to_LLC	Cost readmission – well-nourished, discharged from home to low level care (LLC)	9,304.42	6,532.48
c_WN_LLC_to_HLC	Cost readmission – well-nourished, discharged from low to high level care	25,768.22	17,991.28
c_WN_NoChange_Home	Cost readmission – well-nourished, discharged from home to home	9,586.19	6,728.59
c_WN_NoChange_LLC	Cost readmission – well-nourished, discharged from low to low level care	11,752.39	8,236.26
Fixed costs			
c_RED_direct	Direct cost of RED – discharge planner wage level plus on-cost (section 4.2.2)		56.57

Malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment)

Fig. 4.5 Decision tree model representing Australian usual care and the RED care model – RED treatment effect applied to cost outcome only (12-month base case)



4.2.7 Sensitivity analyses around the conservative 12-month base case

To consider decision making uncertainty, sensitivity analyses were undertaken to consider the base case varying conservative assumptions of 1) no survival benefits and 2) no downstream aged care cost savings.

(1) Survival benefit from malnutrition improvement: The base case is conservative in assuming no survival benefits arise with RED despite expected improved continuity of care and nutritional status of older patients post index hospital admission. In this first sensitivity analysis, the RED treatment effect on post discharge hospital use (RR of 0.696) is considered as a proxy for the RED treatment effect on nutritional status. When applying the RED care model to malnourished and also to at risk patients, the better coordination of care in the hospital, together with the use of primary care post discharge with RED could be expected to lead to an improvement in the patient's health status in general during, but particularly, post hospital discharge with better discharge planning and post hospital care.

To allow for this in sensitivity analysis, for populations that are either malnourished (32.2%) or at risk of malnutrition (54.5%), the probability that they remain in their current malnutrition state is reduced with the RED care model to reflect the RED relative risk for rehospitalisation of 0.696. Hence, 30.4% of the populations with malnutrition or malnutrition risk at initial admission are modelled in sensitivity analysis as improving their nutritional status, whether from malnutrition to at risk or at risk to well-nourished. Combining the shift from malnourished to at risk and at risk to well-nourished, the net effect reduces the malnourished population proportion from 32.2% to 22.4% and at risk patients from 54.5% to 47.7%, while the well-nourished patient proportion increases from 13.3% to 29.9%. Hence, malnourished patients with RED in absolute terms are modelled to be reduced by 9.8%, while at risk patients are reduced by 6.8% and the well-nourished patient group increases by 16.6%.

These risks for being malnourished, at risk or well-nourished is subsequently multiplied by the respective survival rate for each nutritional state as calculated in results section 4.1.1. The net expected impact of this nutritional status improvement with RED is in an overall increase in survival rate to 89.1%, from 87.1% with usual care. Hence, as shown in Table 4.11, this sensitivity analysis suggests an absolute 2.0 percentage point increase in overall survival where the RED care model improves the nutritional status of the older acute care patients in line with the RED treatment effect on rehospitalisation.

Table 4.11 Expected 12-month survival benefit given the risk for survival and nutritional status of older patients in the Australian (AUS) acute hospital setting and after applying the RED treatment (Tx) effect

Nutritional status	Malnourished (MNA < 17)	At risk of malnutrition (MNA = 17 – 23.9)	Well-nourished (MNA ≥ 24)	Probability (Overall survival)
Survival rate	0.794	0.897	0.953	
Probability (Nutritional status) - Usual care AUS	32.2	54.5	13.3	87.1
Probability (Nutritional status) - RED Tx adjusted	22.4	47.7	29.9	89.1

MNA (Mini Nutritional Assessment)

Similarly, Fig. 4.6 represents the decision tree model when translating the RED treatment effect to the base risk of the nutritional status in the alternative care arm to show the expected survival benefit with the RED care model. The incremental survival gain again is 0.020 or 2.0 absolute percentage points (i.e. usual care survival at 12 months of 0.871 versus RED 0.891), as in Table 4.11.

Applying the RED treatment effect to transitioning from being malnourished to at risk and at risk to well-nourished, has expected impacts on incremental costs, as well as health effects. Expected incremental cost savings with RED increased from AUD 3,950.82 (AUD 13,182.31 with usual care compared to AUD 9,231.49 with RED) to AUD 4,015.60 per patient (AUD 13,182.31 with usual care compared to AUD 9,166.71 with RED, Fig. 4.7), given the net impact on the proportion of the population malnourished (from 32.2% to 22.4%), at risk of malnutrition (from 54.5% to 47.7%) or well-nourished (from 13.3% to 29.9%).

Fig. 4.6 Decision tree model representing Australian usual hospital care and the RED care model - RED treatment effect applied to nutritional status and cost outcome (12-month survival benefit)

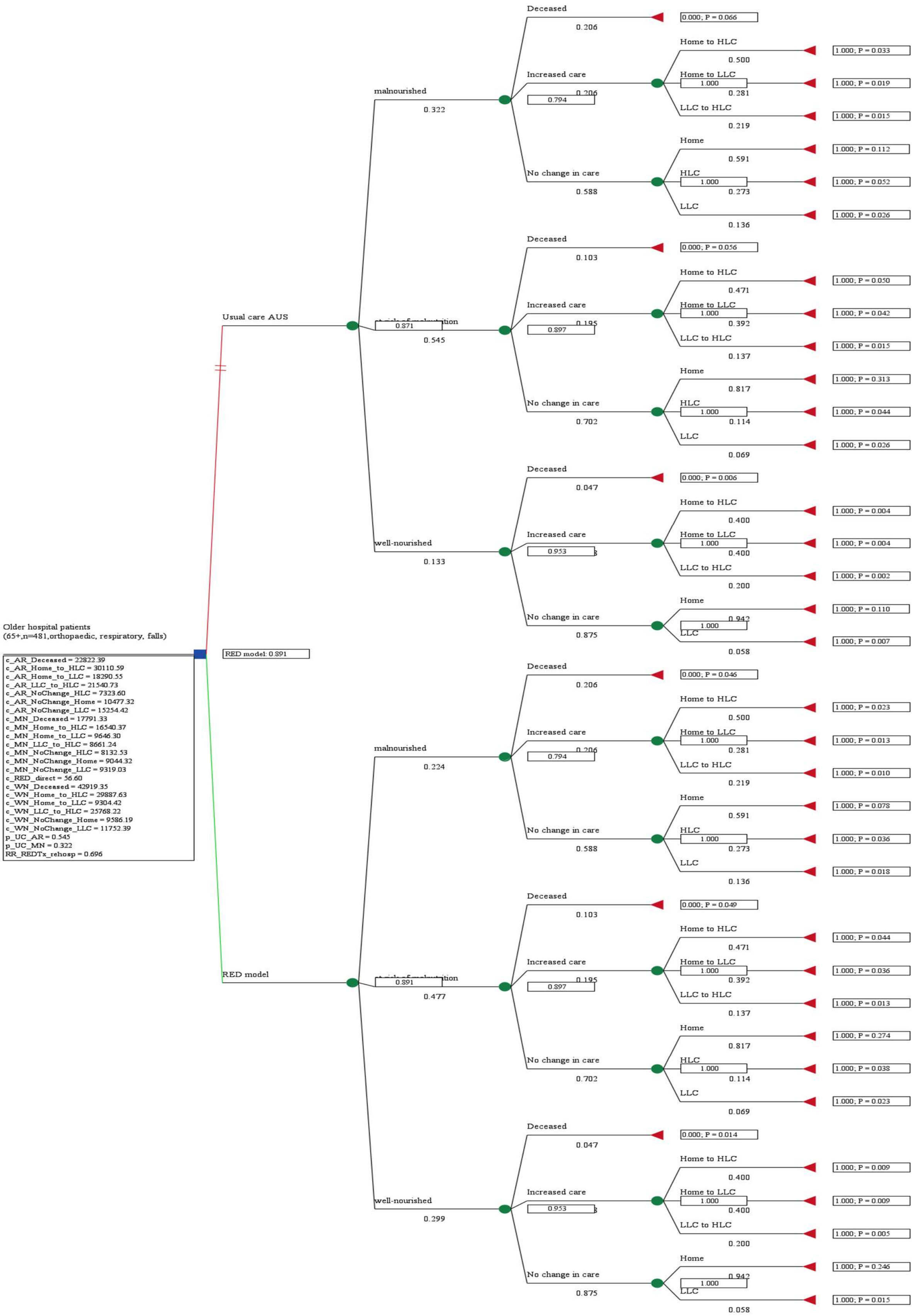
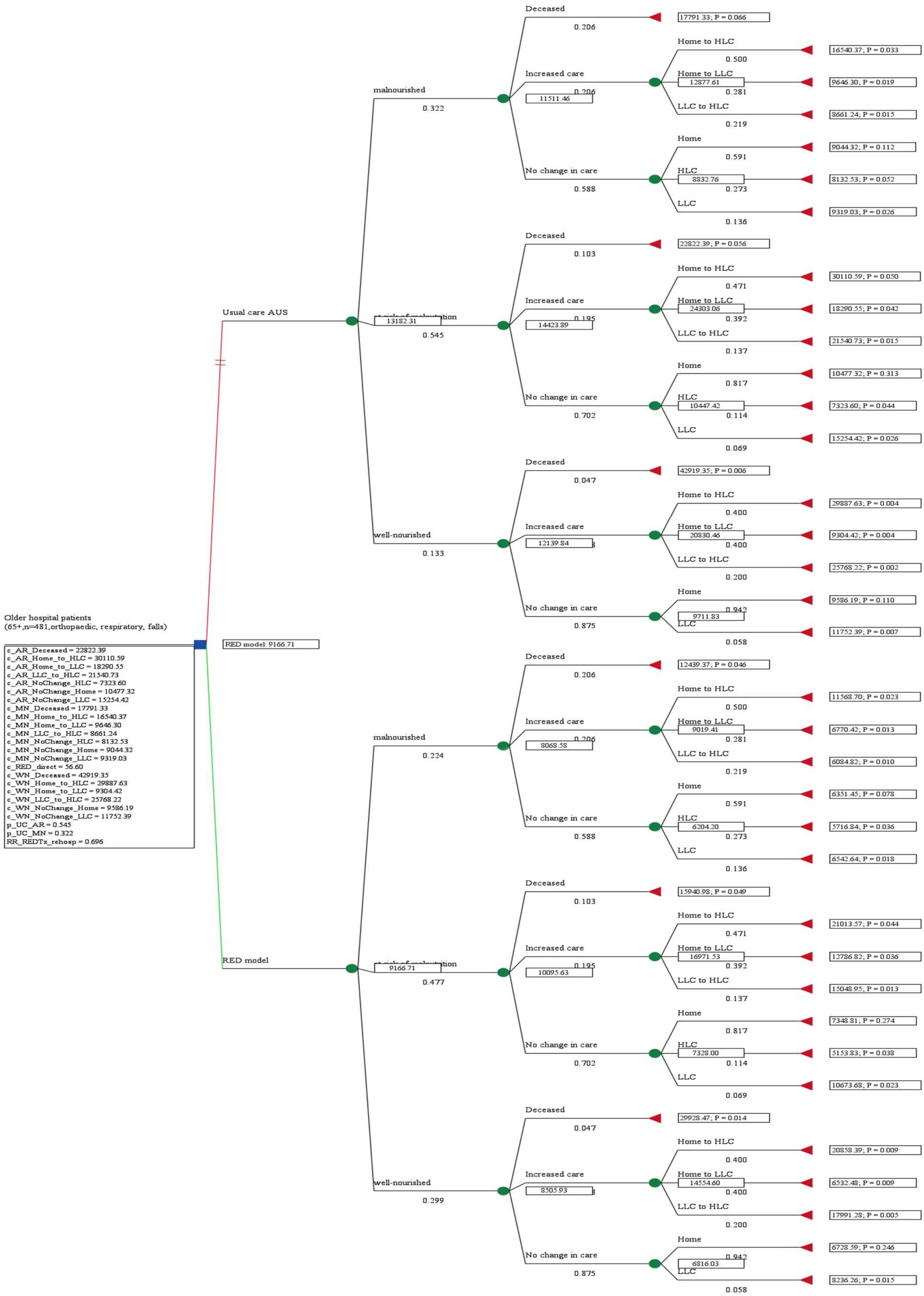


Fig. 4.7 Decision tree model representing Australian usual hospital care and the RED care model – RED treatment effect applied to nutritional status and cost outcome (12-month cost benefit)



(2) Downstream aged care cost savings: In the first sensitivity analysis, the RED treatment effect was applied to the base risk of the nutritional status and to the cost outcome of the RED care model in the decision tree (Fig. 4.6 and 4.7). In the second sensitivity analysis, costs of low level (hostel) or high level (nursing home) care are also included, modelled based on the older patients final hospital discharge destination and the time of that discharge (refer to Fig. 4.8).

The additional low and high level care costs within each nutrition group were determined from the number of days from the patient's last discharge date until the end of their 12 months follow-up period (Table 4.12) multiplied by the average daily subsidy rate for relevant low level or high level residential respite care (Table 4.13). The daily subsidy rates were calculated based on 'Aged care subsidies and supplements', covering the payment rates from 1st July 2008 to 30th June 2012, Department of Health, Australian Government web archive; noting that the study population index admissions span over two years, from 1st January 2009 to 31st December 2010 and additionally include a 12 month follow-up period from date of index admission. In Table 4.14, the costs including the additional high and low level residential aged care costs modelled by health state with Australian usual care or the RED care model are presented.

Comparing the average number of days spent in high or low level care over a one year follow-up for older patients, who entered such care (Table 4.12), shows a greater proportion of malnourished patients and their earlier entry into high level or nursing home care. For the malnourished older population, 30.9% entered high level care within a year and on average spent 294 days there up to one year. This compares to 19.9% of at risk patients entering high level care and spending on average 205 days up to one year and 4.7% of well-nourished patients entering high level care and spending 203 days up to one year. Across the older patient study population (i.e. both those who have and do not have high level care after presenting for an index admission), this leads to an average of 91 days in high level care for malnourished patients, 41 days for at risk patients and 10 days for well-nourished patients. High level aged care costs for malnourished patients are consequently AUD 9,364.81 (91 days multiplied by AUD 102.91), AUD 5,145.50 (AUD 9,364.81 less 4,219.31) higher than for at risk patients and AUD 8,335.71 (AUD 9,364.81 less 1,029.10) higher than that for well-nourished patients.

Table 4.12 Average time an older patient spent in low level care (LLC, hostel) or high level care (HLC, nursing home) based on the hospital discharge and readmission data of the study hospital and the nutritional status of the hospital study population

Patient group	Proportion of population having		Average number of days for those who spent time in		Average number of days per patient	
	LLC	HLC	LLC	HLC	LLC	HLC
Malnourished	0.135	0.309	210	294	28	91
At risk of malnutrition	0.126	0.199	232	205	29	41
Well-nourished	0.078	0.047	116	203	9	10

Malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment)

Table 4.13 Daily subsidy rates for either low or high level residential respite care based on 'Aged care subsidies and supplements', covering payment rates from July 2008 – June 2012 (Department of Health, Australian Government web archive)

Years	Daily subsidy rates	
	Low level residential respite care	High level residential respite care
1 July 2008 - 30 June 2009	35.70	100.07
1 July 2009 - 30 June 2010	36.38	101.97
1 July 2010 - 30 June 2011	37.03	103.81
1 July 2011 - 30 June 2012	37.73	105.78
Average subsidy rate	36.71	102.91

Including residential aged care costs and the hospital readmission costs, as well as considering change in nutritional status with RED as modelled in the first sensitivity analysis, the expected costs for the RED care model are AUD 14,398.40 per patient compared to usual care of AUD 19,570.72. Hence, the expected incremental net cost savings with RED including aged care as well as health care costs is AUD 5,172.32 per patient, see Fig. 4.8. This results in an additional expected cost saving of AUD 1,156.72 modelled with RED; reflecting the increase from AUD 4,015.60 (first sensitivity analysis) to AUD 5,172.32.

Fig. 4.8 Decision tree model representing Australian usual hospital care and the RED care model – RED treatment effect applied to nutritional status and cost outcome (12-month aged care cost benefit)

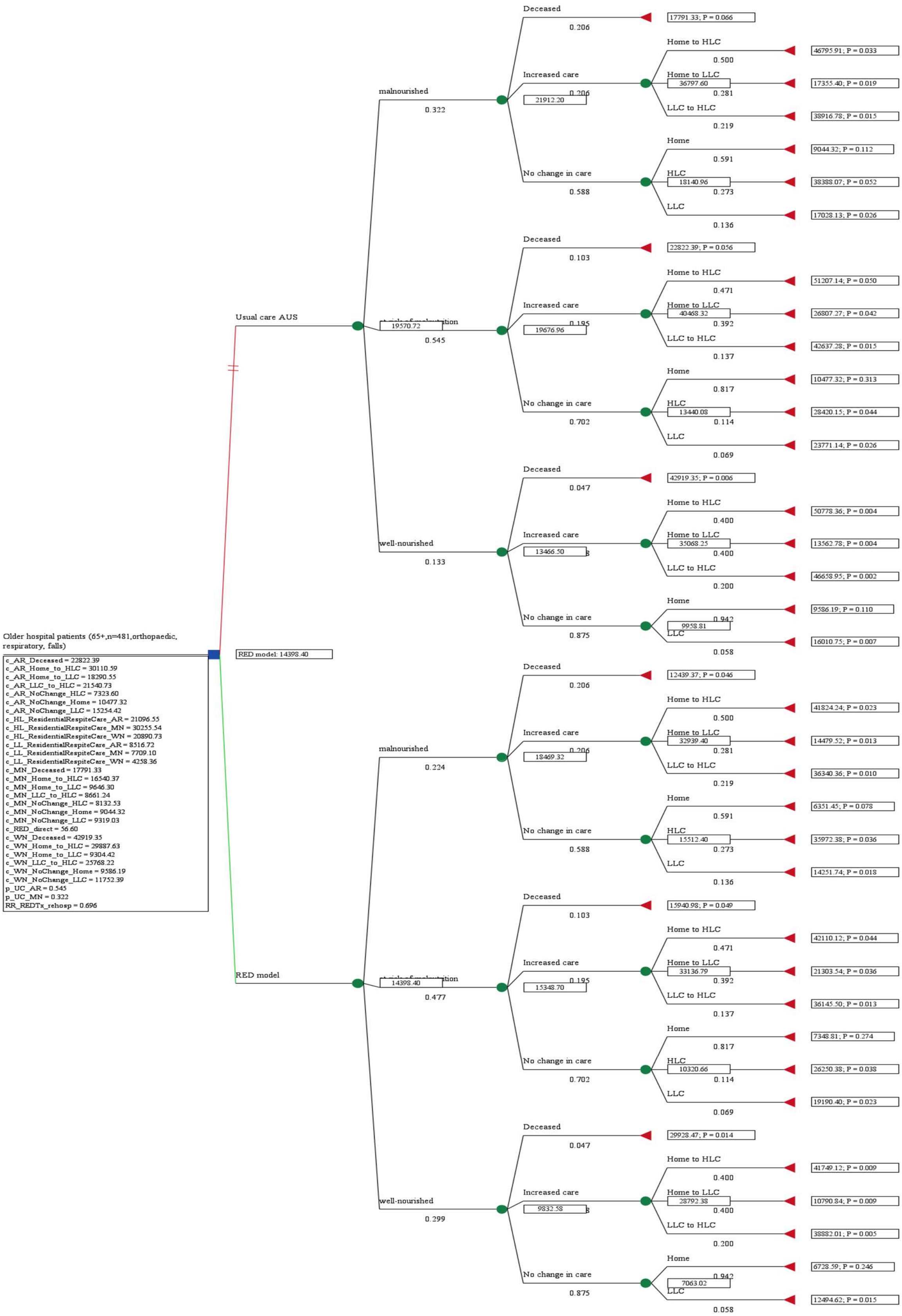


Table 4.14 12-month costs modelled by health state with Australian usual care or the RED care model for sensitivity analysis 2, including residential aged care costs

Name	Description	Cost Usual care	Cost RED model
Malnourished patients			
c_MN_Deceased	Cost (c) readmission - malnourished deceased patients	17,791.33	12,439.37
c_MN_Home_to_HLC	Cost readmission – malnourished, discharged from home to high level care (HLC)	46,795.91	41,824.24
c_MN_Home_to_LLC	Cost readmission – malnourished, discharged from home to low level care (LLC)	17,355.40	14,479.52
c_MN_LLC_to_HLC	Cost readmission – malnourished, discharged from low to high level care	38,916.78	36,340.36
c_MN_NoChange_HLC	Cost readmission – malnourished, discharged from high to high level care	38,388.07	35,972.38
c_MN_NoChange_Home	Cost readmission – malnourished, discharged from home to home	9,044.32	6,351.45
c_MN_NoChange_LLC	Cost readmission – malnourished, discharged from low to low level care	17,028.13	14,251.74
At risk patients			
c_AR_Deceased	Cost (c) readmission – at risk deceased patients	22,822.39	15,940.98
c_AR_Home_to_HLC	Cost readmission – at risk, discharged from home to high level care (HLC)	51,207.14	42,110.12
c_AR_Home_to_LLC	Cost readmission – at risk, discharged from home to low level care (LLC)	26,807.27	21,303.54
c_AR_LLC_to_HLC	Cost readmission – at risk, discharged from low to high level care	42,637.28	36,145.50
c_AR_NoChange_HLC	Cost readmission – at risk, discharged from high to high level care	28,420.15	26,250.38
c_AR_NoChange_Home	Cost readmission – at risk, discharged from home to home	10,477.32	7,348.81
c_AR_NoChange_LLC	Cost readmission – at risk, discharged from low to low level	23,771.14	19,190.40
Well-nourished patients			
c_WN_Deceased	Cost (c) readmission – well-nourished deceased patients	42,919.35	29,928.47
c_WN_Home_to_HLC	Cost readmission – well-nourished, discharged from home to high level care (HLC)	50,778.36	41,749.12
c_WN_Home_to_LLC	Cost readmission – well-nourished, discharged from home to low level care (LLC)	13,562.78	10,790.84
c_WN_LLC_to_HLC	Cost readmission – well-nourished, discharged from low to high level care	46,658.95	38,882.01
c_WN_NoChange_Home	Cost readmission – well-nourished, discharged from home to home	9,586.19	6,728.59
c_WN_NoChange_LLC	Cost readmission – well-nourished, discharged from low to low level care	16,010.75	12,494.62
Fixed costs			
c_RED_direct	direct cost of RED – discharge planner wage level plus on-cost		56.57
c_HL_ResidentialRespiteCare_MN	days in care (e.g. 294, **Table 4.12**) multiplied by daily subsidy rate (AUD 102.91, **Table 4.13**)		30,255.54

c_HL_ResidentialRespiteCare_AR	21,096.55
c_HL_ResidentialRespiteCare_WN	20,890.73
c_LL_ResidentialRespiteCare_MN	7,709.10
c_LL_ResidentialRespiteCare_AR	8,516.72
c_LL_ResidentialRespiteCare_WN	4,258.36

Malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment)

4.2.8 Sensitivity analysis for conservative incremental cost-effectiveness 30-day readmission cost analysis

Considering a very conservative analysis of expected readmission cost impact of RED for the older patient population, the relative treatment effect on readmission could be restricted to the readmission costs at 30 days post index discharge. The expected readmission cost reduction, this leads to, would be AUD 371.26 per patient (Table 4.15). Deducting the estimated RED implementation cost of AUD 56.57 results in an overall net cost saving of AUD 314.69 per patient. This estimated downstream cost reduction is based on the statistically significant RED treatment effect of 30.4% relative risk reduction in rehospitalisation.

4.2.9 Modelled sensitivity analysis for 30-day readmission costs

Figure 4.9 shows the decision tree for comparing Australian usual care with what could be expected if the RED relative risk reduction in rehospitalisation of 30.4% is applied only to downstream usual care hospital costs at 30 days. The decision tree rolled back confirms a net health system cost saving of AUD 319.07 with the RED care model (AUD 916.67) versus usual care in Australia (AUD 1,235.74). The expected base case costs (excluding index admission cost) modelled by nutrition status with Australian geriatric usual care or the RED care model are listed in the corresponding Table 4.16.

Alternatively, if the RED relative treatment effect of 33.9% relative risk reduction in overall health care costs would have been applied to the 30-day rehospitalisation costs of the study hospital, the readmission costs reduce by AUD 414.00 (AUD 1,221.24 with usual care and AUD 807.24 with RED, Table 4.15). There would be an overall cost saving of AUD 357.33 (414.00 minus 56.57). Figure 4.10 shows the decision tree after applying the RED relative risk reduction of 33.9% in health care costs to the 30-day readmission costs across the older patient population. It leads to a net cost saving of AUD 362.32 comparing the RED care model (AUD 873.42) versus usual care in Australia (AUD 1,235.74).

Table 4.15 Breakdown of mean DRG weights and costs from hospital admissions as well as the expected RED adjusted costs in the malnourished, at risk and well-nourished older patients at 30 days of index discharge

Usual care AUS	Malnourished patients (n=155)	At risk patients (n=262)	Well-nourished patients (n=64)	Weighted average Total population (n=481)
Mean DRG weight per patient - index admissions	3.414	3.518	2.838	3.394
Mean DRG weight per patient - all inpatient admissions up to 30d	3.657	3.791	3.015	3.644
Mean DRG weight per patient - readmissions 30d after index admission	0.265	0.286	0.176	0.265
Readmission rate 30d				
National cost/DRG weight (AUD), Round 15, 2010-11, acute public hospitals	4,613.00			
NSW cost/DRG weight (AUD)	4,576.00			
Mean cost index admissions (based on National average, AUD)	15,748.30	16,229.65	13,093.57	15,657.26
Mean cost all inpatient admissions (AUD) up to 30d	16,971.67	17,549.21	13,907.19	16,878.51
Mean cost readmissions (AUD) up to 30d	1,223.37	1,319.56	813.62	1,221.24
Expected impact of RED Treatment effect				
RR Hospital utilisation	0.696			
RR Health care costs	0.661			
Expected mean DRG weight from readmissions (30.4% relative risk reduction, RRR)	0.184	0.199	0.123	0.184
Expected mean DRG weight from readmissions (33.9% RRR)	0.175	0.189	0.116	0.121
Expected mean cost readmissions (AUD) up to 30d (30.4% RRR)	851.47	918.41	566.28	849.99
Expected mean cost readmissions (AUD) up to 30d (33.9% RRR)	808.65	872.23	537.80	807.24
Cost reductions expected for readmissions (based on Nat. aver., AUD, 30.4% RRR)	371.90	401.15	247.34	371.26
Cost reductions expected for readmissions (based on Nat. aver., AUD, 33.9% RRR)	414.72	447.33	275.82	414.00
Expected mean DRG weight from index admissions	2.376	2.449	1.975	2.362
Expected mean cost index admissions (AUD) up to 30d	10,960.82	11,295.84	9,113.12	10,897.45
Cost reductions expected for index admissions (based on Nat. aver., AUD)	4,787.48	4,933.81	3,980.45	4,759.81
Expected mean DRG weight from all inpatient admissions	2.545	2.638	2.098	2.537
Expected mean cost all inpatient admissions (AUD) up to 30d	11,812.28	12,214.25	9,679.40	11,747.44
Cost reductions expected for all inpatient admissions (based on Nat. aver., AUD)	5,159.39	5,334.96	4,227.79	5,131.07

DRG (Diagnosis Related Group), malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment), RR (Relative risk), RRR (Relative risk reduction)

Fig. 4.9 Base case decision tree model representing Australian usual care and the RED care model – 30.4% RED relative risk reduction applied to the 30-day cost outcome

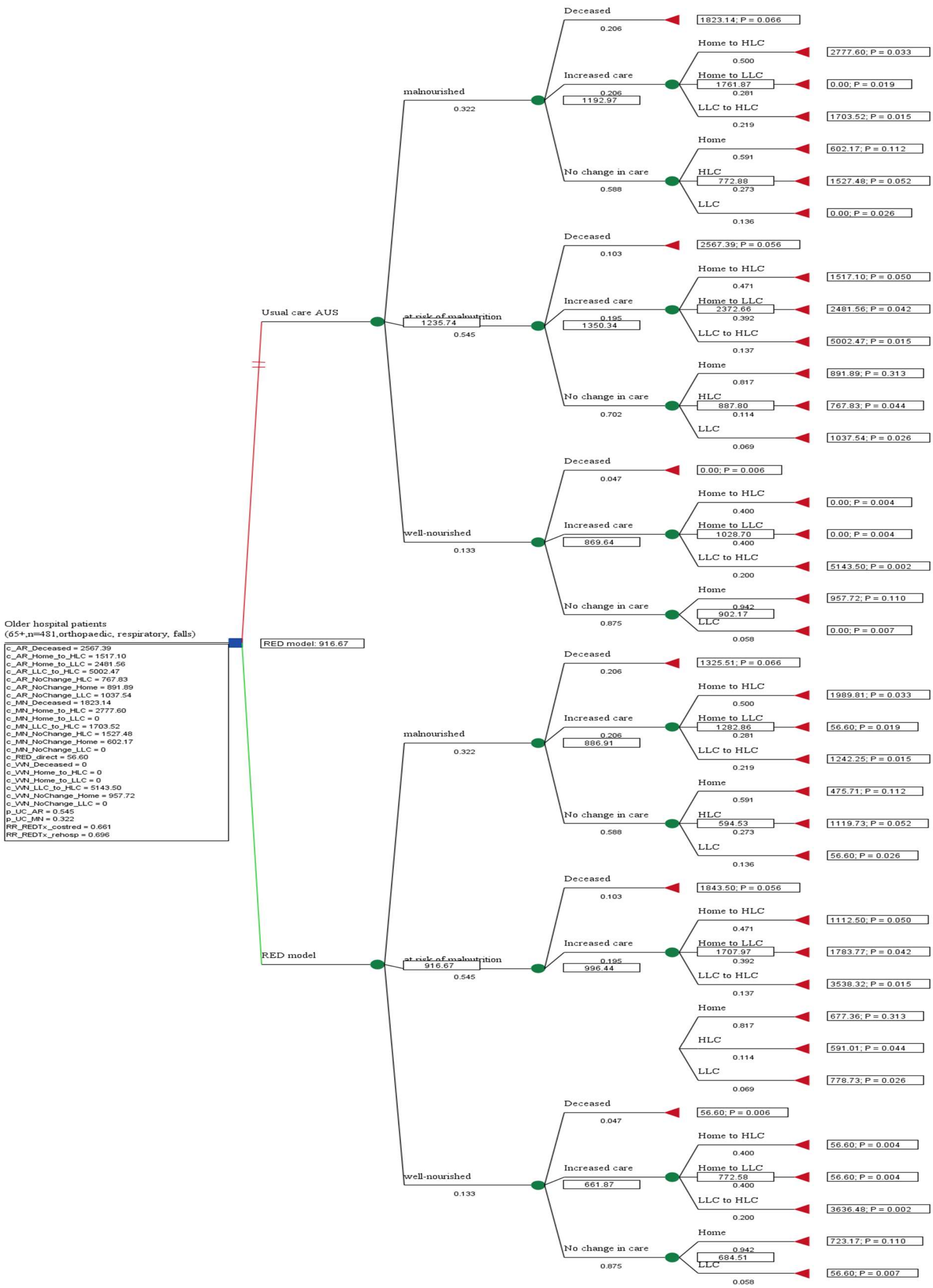
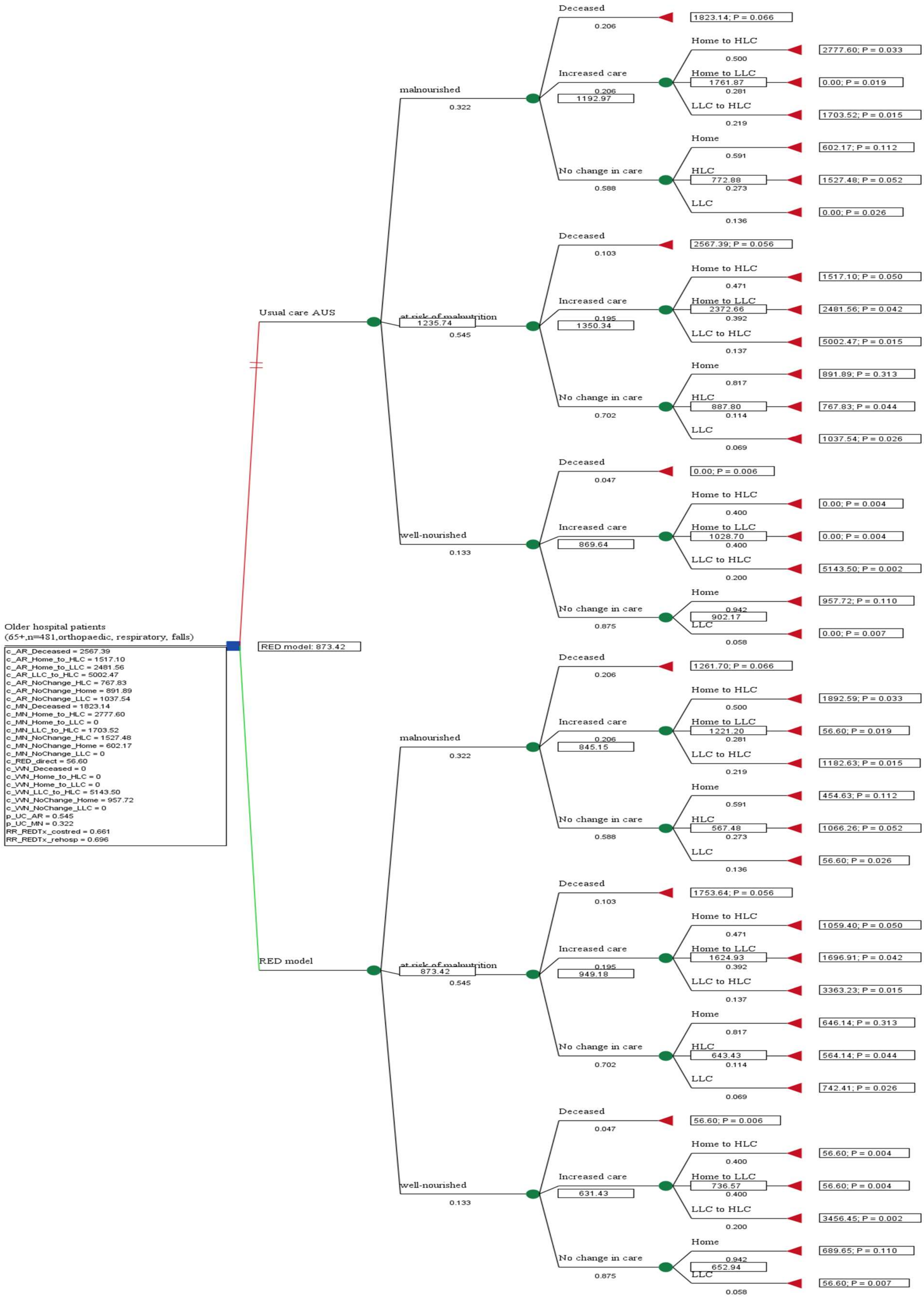


Table 4.16 Expected base case costs (in AUD) of the 30-day hospital readmissions in geriatric usual care in Australian practice and with the RED care model at each terminal node in the decision tree

Name	Description	Cost Usual care	Cost RED model
Malnourished patients (MN)			
c_MN_Deceased	Cost (c) readmission - malnourished deceased patients	1,823.14	1,325.51
c_MN_Home_to_HLC	Cost readmission – malnourished, discharged from home to high level care (HLC)	2,777.60	1,989.81
c_MN_Home_to_LLC	Cost readmission – malnourished, discharged from home to low level care (LLC)	0	56.57
c_MN_LLC_to_HLC	Cost readmission – malnourished, discharged from low to high level care	1,703.52	1,242.25
c_MN_NoChange_HLC	Cost readmission – malnourished, discharged from high to high level care	1,527.48	1,119.73
c_MN_NoChange_Home	Cost readmission – malnourished, discharged from home to home	602.17	475.71
c_MN_NoChange_LLC	Cost readmission – malnourished, discharged from low to low level care	0	56.57
At risk patients (AR)			
c_AR_Deceased	Cost (c) readmission – at risk deceased patients	2,567.39	1,843.50
c_AR_Home_to_HLC	Cost readmission – at risk, discharged from home to high level care (HLC)	1,517.10	1,112.50
c_AR_Home_to_LLC	Cost readmission – at risk, discharged from home to low level care (LLC)	2,481.56	1,783.77
c_AR_LLC_to_HLC	Cost readmission – at risk, discharged from low to high level care	5002,47	3,538.32
c_AR_NoChange_HLC	Cost readmission – at risk, discharged from high to high level care	767.83	591.01
c_AR_NoChange_Home	Cost readmission – at risk, discharged from home to home	891.89	677.36
c_AR_NoChange_LLC	Cost readmission – at risk, discharged from low to low level	1,037.54	778.73
Well-nourished patients (WN)			
c_WN_Deceased	Cost (c) readmission – well-nourished deceased patients	0	56.57
c_WN_Home_to_HLC	Cost readmission – well-nourished, discharged from home to high level care (HLC)	0	56.57
c_WN_Home_to_LLC	Cost readmission – well-nourished, discharged from home to low level care (LLC)	0	56.57
c_WN_LLC_to_HLC	Cost readmission – well-nourished, discharged from low to high level care	5,143.50	3,636.48
c_WN_NoChange_Home	Cost readmission – well-nourished, discharged from home to home	957.72	723.17
c_WN_NoChange_LLC	Cost readmission – well-nourished, discharged from low to low level care	0	56.57
Fixed costs			
c_RED_direct	Direct cost of RED – discharge planner wage level plus on-cost		56.57

Malnourished (MNA < 17), at risk of malnutrition (MNA = 17 - 23.9), well-nourished (MNA ≥ 24), MNA (Mini Nutritional Assessment)

Fig. 4.10 Base case decision tree model representing Australian usual care and the RED care model – 33.9% RED relative risk reduction applied to the 30-day cost outcome



4.2.10 Threshold analyses

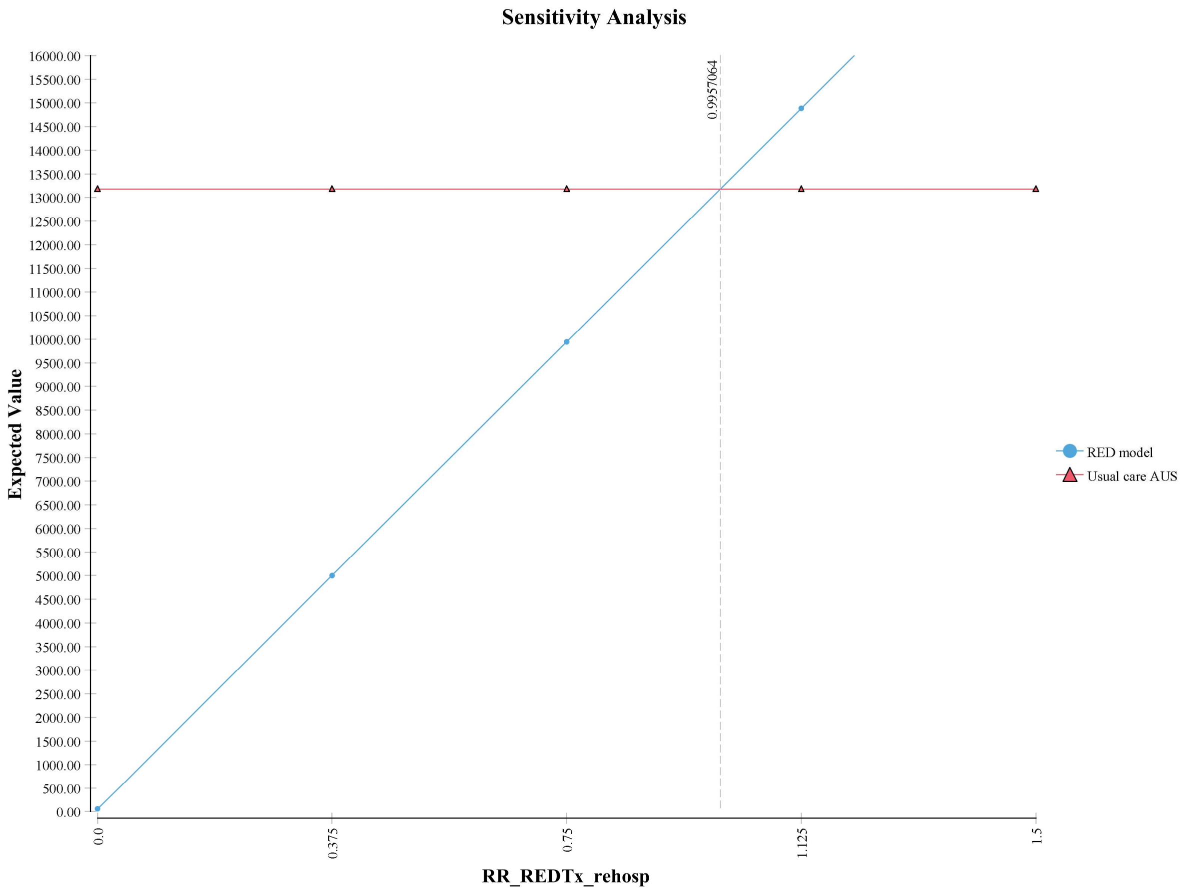
Threshold analyses were undertaken to determine what the threshold values for the RED relative treatment effect on reduction in rehospitalisations would be for the RED care model to become cost saving to the health system in treating over 65 patients presenting in hospital in terms of downstream treatment effects on 12 month readmission rates alone and readmission and aged care use combined.

Given the reported additional direct cost of the RED discharge nurse advocate of AUD 56.57 in the index admission and the AUD 13,182.31 readmission cost over 12 months, the threshold value for the RED treatment effect at which RED becomes cost saving is 0.004291 or 0.43% (56.57 divided by 13,182.31). Similarly in Fig. 4.11, the threshold analysis in TreeAge shows that both care models are equal at the 0.9957 threshold level for the RED relative risk of rehospitalisation, and relative risk levels lower than this threshold mean that RED has lower expected cost than usual care. This treatment effect of 0.43% (1 - 0.9957 = 0.0043) is many orders of magnitude less than the RED treatment effect for rehospitalisation of 30.4% or 33.9% for health system costs reported by Jack et al. (2009).

In a second threshold analysis, both the readmission cost over 12 months and the residential aged care costs up to 12 months are considered. In this case, the treatment effect in terms of relative risk reduction required for the RED care model to be cost saving is 0.002891 (56.57 divided by 19,570.72) or 0.29%. The threshold is less again than that of the threshold considering the 12-month readmission cost and again far less compared to the downstream 30.4% rehospitalisation reduction and 33.9% cost reduction that RED points to.

In the third threshold analysis, the threshold level of the treatment effect at which RED becomes cost saving is calculated based on the readmission costs at 30 days of index discharge (AUD 1,235.74, Fig. 4.10) across the older patient population and the direct RED cost (AUD 56.57). That threshold level for the treatment effect is 0.0458 or 4.6% (56.57 divided by 1,235.74), which still remains far less compared to the 30.4% or 33.9% relative risk reduction shown with the RED treatment effect on rehospitalisation or health system costs, respectively, reported by Jack et al. (2009) (Fig. 4.12).

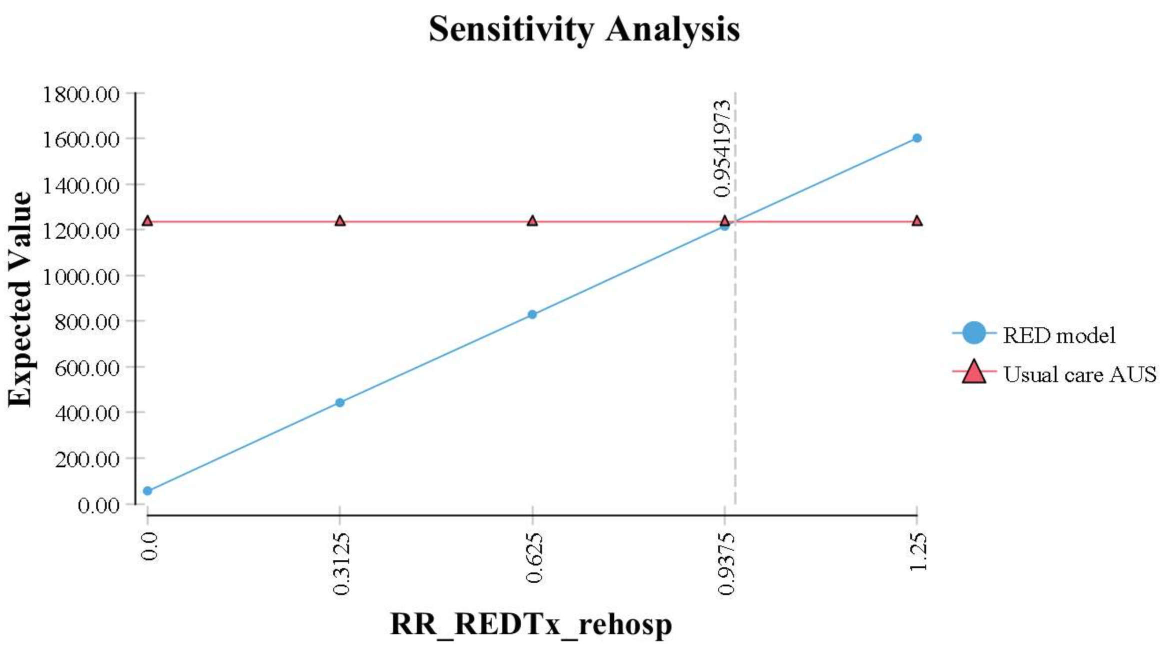
Fig. 4.11 Threshold analysis for the RED relative risk level (note RRR= 1-RR) at which the RED model becomes cost saving to the health system in treating older hospitalised patients (12-month hospital readmission costs)



*Note the RR threshold of 0.9957 implies that the RED model of care becomes cost saving with a RRR of 0.0043 (1 - 0.9957 = 0.0043)

RED (Re-Engineered Discharge) model, RR (Relative risk), RRR (Relative risk reduction)

Fig. 4.12 Threshold analysis for the RED relative risk level (note RRR= 1-RR) at which the RED model becomes cost saving to the health system in treating older hospitalised patients (30-day hospital readmission costs)



*Note the RR threshold of 0.9542 implies that the RED model of care becomes cost saving with a RRR of 0.046 (1-0.954).

RED (Re-Engineered Discharge) model, RR (Relative risk), RRR (Relative risk reduction)

4.2.11 Summary of base case and sensitivity analyses

In Table 4.17, base case and sensitivity analysis results are summarised for costs, health outcomes and the differences comparing the RED care model versus Australian usual care and Fig. 4.13 shows INB curves. The INB (INB = $\Delta E * \lambda - \Delta C$) is shown across a range of threshold value (λ) applied to incremental survival ($\Delta E = 0.02$). The Fig. 4.13 shows that given expected net costs savings no positive threshold value is necessary and even if the decision maker is not willing to pay anything ($\lambda = 0$), the RED model is still better than Australian usual care.

Fig. 4.13 Incremental net benefit (INB) curves of the RED care model versus usual care based on Table 4.17 summarising base case and sensitivity analyses (SA)

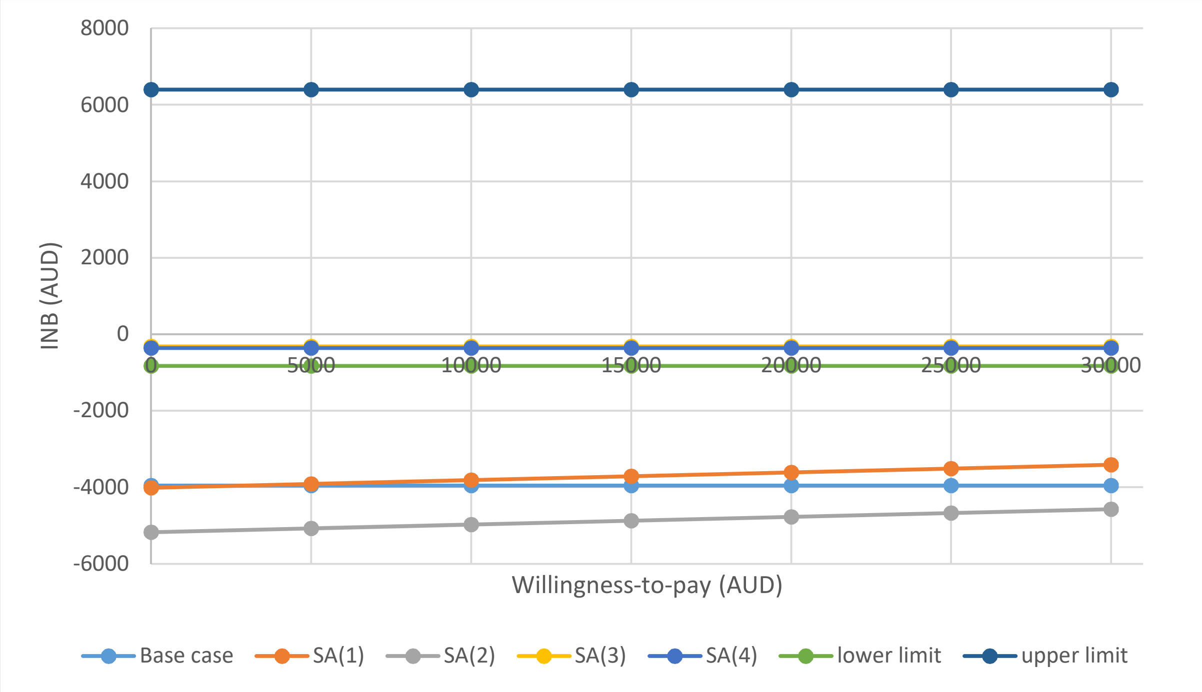


Table 4.17 Summarised base case and sensitivity analyses results for costs, health effects and the increments comparing the RED care model versus Australian usual care

	Readmission cost (AUD)		Aged care cost (AUD)		Incremental cost (ΔC)	Survival		Incremental survival (ΔE)
	Usual care	RED model	Usual care	RED model		Usual care	RED model	
Base case – 12mth	13,182	9,231	-	-	3,951	-	-	-
Sensitivity analysis (1) Survival & cost benefit	13,182	9,167	-	-	4,015	0.871	0.891	0.020
Sensitivity analysis (2) Survival & aged care cost benefit	19,570	14,398	6,388	5,231	5,172	0.871	0.891	0.020
Sensitivity analysis (3) 30d readmission costs (RRR 30.4%)	1,235	916	-	-	319	-	-	-
Sensitivity analysis (4) 30d readmission costs (RRR 33.9%)	1,235	873	-	-	362	-	-	-
Sensitivity analysis (5) 95% CI RED relative Tx (0.515 – 0.937)	13,182	6,788 – 12,351	-	-	831 – 6,394	-	-	-

5 DISCUSSION

The objective of this thesis has been to inform health and aged care decision makers about the cost-effectiveness of an integrated hospital care and discharge process to improve health system care and cost impacts for malnourished older patients presenting in acute care hospitals in Australia. The thesis has addressed this with evidence synthesis of nutritional epidemiological studies of older patients characterised as being malnourished or at risk of malnutrition in an Australian acute hospital with trial evidence from an alternative 'Re-Engineered Discharge' (RED) care model that has demonstrated potential to reduce rehospitalisations, as well as addressing care continuity across the health and aged care system more generally.

Specifically, by reinterpreting the data and adding to the results from Charlton et al. (2013) using a smaller but more homogenous patient subsample, as is required for robust health economics analysis, standardised odds ratio and Kaplan-Meier survival analysis (section 4.1.2) showed that malnourished older patients had a higher rate of in-hospital mortality and/or discharge to higher level of care within 12 months of follow-up than well-nourished patients. The high prevalence of malnutrition in the older hospital population, combined with increased risk of in-hospital mortality, increased rehospitalisations and total length of stay and use of high level aged care within 12 months, provided the natural history basis for CEA that compared usual care in Australia with RED as a promising alternative hospital care and discharge strategy.

Malnutrition not improving in older patients in acute care nor subsequently in post-discharge health and aged care settings is characteristic of current usual care. This is the case where hospitals objectives under case-mix funding are to minimise cost per admission in public hospitals and can easily lead to quicker, sicker care rather than net benefit maximising health system quality of care appropriately allowing for downstream impacts (Eckermann 2004, Eckermann and Coelli 2013). In particular, this can result in higher care needs, readmission rates and downstream health and aged care costs. In order to address nutrition and care issues arising in acute older populations and impacting across care settings, an alternative strategy that improves system quality of care allowing for joint in-hospital and post-discharge effects and costs of care was considered in this thesis (Falster et al. 2016, Swerissen and Duckett 2016, Eckermann and Coelli 2013).

Through a comprehensive literature review on the continuity of care (section 2.6), the RED care model designed by Jack et al. (2008, 2009) to reduce rehospitalisations, was identified as being a preferred strategy that facilitated appropriate primary health care in the hospital and linking it to the patient's care post-discharge in the community. This is achieved through patient-centered education, comprehensive in and after hospital care planning and post-discharge reinforcement, which is particularly key for an integrated care of older malnourished populations. That is, where current models with fragmented care and lack of care linkage fail (Swerissen and Ducket 2016).

The clinical evidence on malnutrition prevalence and survival rate in the older hospitalised patient population in Australia and the evidence on reductions in rehospitalisations and cost with RED (the RED treatment effect) were synthesised and the RED treatment effect translated to the jurisdiction of interest, namely Australia (sections 3.2.1, 3.2.3 and 3.3). Base case health economic analysis was conservative assuming that RED had only benefits in terms of cost reductions from lower hospital readmissions. Since the cost savings from readmissions avoided with RED were of a similar magnitude for malnourished, at risk and well-nourished older populations, RED is translated into usual care practice including all older inpatients 65+, not just those that were malnourished. Overall, the expected downstream within-hospital cost savings if RED was implemented into usual care practice across the older hospital population were estimated to be in the order of an average AUD 4,000 per patient. This leads to a net cost saving allowing for the additional expected direct cost for discharge nurse to coordinate the RED strategy (AUD 57 per patient) of AUD 3,951 per patient. Even the estimated AUD 57 cost of RED in the index admission is conservative noting that the additional direct RED cost of the discharge planner within admission potentially substitutes for other health system resources, like discharge-planning personnel, in usual care practice. This would include the time of medical staff (i.e. specialists, registrars and residents), nursing staff, liaison officers, therapists (i.e. physiotherapists, occupational therapists, dietitians, speech pathologists, podiatrists) and social workers involved in arranging discharge and related activities such as health or aged care assessments and discharge summaries (Grimmer et al.

2004). In the RED care model, such activities are the responsibility of the discharge nurse (Jack et al. 2009).

Additional to the in-hospital cost savings, further potential cost savings would be expected where, across hospital and post discharge care, the RED care model shifts patients from being malnourished to either become nutritionally at risk or well-nourished. Indeed, sensitivity analysis (section 4.2.7) shows that if RED had an equivalent treatment effect to that for rehospitalisation in improving patient nutritional status from that at admission (e.g. malnourished to well-nourished), the cost of aged care use could be expected to decrease by AUD 8,300 per patient. Incorporating savings from high level aged care costs avoided at a population level reduces cost with RED by approximately AUD 1,200 per patient and consequently in the order of AUD 5,200 combined with expected reduction in rehospitalisations costs to 12 months.

In general, expected additional direct costs of applying the RED care model (AUD 57) to older patient populations in Australia who have high care costs, are offset by many orders of magnitude by greater hospital and aged care cost reductions over the period of one year following an index admission. Even for a worst case scenario, with additional costs over and above the incremental cost of the discharge nurse and for an increase rather than reduction in hospital length of stay for the index admission, the RED care model remains overall net cost saving to the health system. That is, unless such cost increases exceed the expected AUD 4,000 downstream hospital cost savings and AUD 5,200 with aged care cost reductions.

There are not only cost reductions expected with RED, but also improvements in health system care and health/nutritional status, given the high malnutrition risk in the older 65+ population, are expected across acute and post-discharge settings. Hence, the RED treatment effect on post discharge hospital use (0.696 RR) was considered as a proxy for the treatment effect on older adults' nutritional status (i.e. malnourished or at risk of malnutrition). The sensitivity analysis in section 4.2.7 that varied the conservative assumption of no survival benefits to allow for malnutrition improvement, estimates an absolute 2.0 percentage point increase in survival with such malnutrition status improvement when implementing RED.

This sensitivity analysis synthesised the strong evidence for survival gains with better nutrition, the observed high base risk of older hospitalised patients being malnourished and the potential for RED to improve nutritional status because of better acute and post-discharge nutrition-related care. The conservative base case only considered cost savings with RED from avoided rehospitalisations, to estimate a net cost saving of AUD 4,000. In satisfying health economic principles of coverage and consistent joint consideration of costs and effects, survival benefits from improved nutrition and downstream aged care use associated with nutritional status improvement were incorporated in section 4.2.7. Employing the RED treatment effect on reductions in rehospitalisations to improvement in nutritional status of malnourished and at risk patients, the net cost savings from the RED care model increased to the order of AUD 5,200 per patient and provided a net absolute survival benefit of 2% at 12 months.

The threshold analyses in section 4.2.10 determined very low threshold values (0.29-0.43%) for the RED relative treatment effect of the RED care model to become cost saving to the health system in addressing hospital malnutrition in older patients. This was the case in terms of downstream treatment effects on 12-month readmission rates alone and 12-month hospital readmission and aged care use combined. The RED treatment effect on rehospitalisation (based on interdisciplinary care, nutrition consultation, discharge planning and post-discharge services) can be expected, in older patients with malnutrition, to endure for 12 months after index discharge, given the predicative nature of malnutrition for both clinical issues as well as broader care needs (Naylor et al. 1999, Mudge et al. 2012, Shyu et al. 2013). In this older patient population at high risk of malnutrition, improvements in hospital/nutrition and discharge care do not take immediate effect but develop over time and could even last longer than 12 months as reported by Shyu et al. (2016). These authors extended their previous study results (Shyu et al. 2013) on health outcome improvements of older Taiwanese patients by exploring the relative effects of an interdisciplinary care and a comprehensive care program versus usual care on self-care ability, health care use and mortality over two years after hip-fracture. Their results reinforced a comprehensive care program with geriatric assessment, rehabilitation, discharge planning, nutrition, falls prevention and depression management that led to enhanced self-care ability and decreased emergency department visits, but no difference in mortality during the two-year follow-up.

Threshold analysis also showed that the RED model of care is still cost saving even where a highly conservative sensitivity analysis consideration restricted to 30 day readmissions. This naturally points to the key policy issue of the need for better coordination of and discharge care within hospital but, particularly in the case of malnutrition, connection with community resources and primary health care providers, expected with RED (RED reduced rehospitalisations and increased PCP follow-up visits) beyond an index hospitalisation discharge. Also, given the downstream impacts with the RED model, a shift in resources from hospitals into general practice and community care can be expected. The discharge planner has a central role in implementing the RED care model and for the older population in the Australian acute hospital setting to facilitate timely dietary care of malnourished or at risk patients and access to appropriate primary care post discharge. Importantly, the discharge planner can make the processes of discharge back into the community more efficient for older malnourished or nutritionally at risk patients, by taking over more responsibility in the care coordination in the hospital, at discharge as well as post-discharge and reduce the time of other health care practitioners.

RED emphasises a better coordination of care as well as a better linkage between primary care in hospital and post-discharge in the community or in aged care by leveraging aged care as well as health system Quality of Care (QoC) improvements and cost reductions over time (Jack et al. 2009). Overall, older malnourished or at risk patients with RED are expected to receive better continuity of care between hospital and community settings.

The patient-centered education in RED better prepares the patient for discharge back into the community (Greenwald and Jack 2009, Wrigley 2013), preferably home, rather than referral to aged care settings, and in turn can be expected to help avoid bed blocking in hospital. Lowering aged care needs could also reduce bed blocking and needless increases to length of hospital stay. This more generally could be expected to have a positive impact on the index admission as well as downstream health and aged care service utilisation post-discharge, leading to cost savings to health and aged care systems.

5.1 Comparing results with similar findings in literature to consider policy implications

Jack and his colleagues established the RED care model and its components at the Boston Medical Centre where they conducted their pilot and subsequent randomised controlled trial with general medical patients (Jack et al. 2008, 2009). They showed the RED strategy to have a 30.4% relative reduction in hospital utilisation within 30 days of index discharge and a net cost offset of USD 412 per patient (RED intervention cost excluded) by increasing primary care outpatient visits. Apart from Jack's initial studies, RED has also been successfully implemented in some other American hospitals, including in older hospital populations (Markley et al. 2013). Markley et al. (2013) analysed the Medicare claims data after implementing most of the RED components in a Texas hospital and reported a 36% relative reduction in the 30-day readmission rates. They initially applied RED on heart failure patients to be discharged to home care, and were then able to expand to all inpatient units in that hospital, except for maternity and cancer wards. A Project RED pilot study was conducted in a hospital in Belleville to improve the discharge outcomes for heart failure patients, and showed a 49.4% relative reduction in the 30-day readmission rate in the pilot population and 28.7% facility-wide reduction (Wrigley 2013).

Hence, further studies show decreases in 30-day hospital readmission rates ranging up to 49.4%, and generally greater than or comparable to Jack's 2009 study, however no costs were reported for the latter two studies.

A recent study conducted in five Californian hospitals by Mitchell et al. (2017) considered qualitative aspects to successfully incorporate RED into usual care practice. The authors found that implementation of RED is best undertaken as a transformational process in order to sustain the RED strategy in the hospital. This is, RED requires a culture change in the hospital environment that involves a multidisciplinary implementation team that embraces clear leadership and responsibilities related to following the RED protocol. Clinical trial data demonstrates that RED is a safe, timely, coordinated and patient-centered hospital care and discharge process, that facilitates effective and efficient care transitions for patients discharged from hospital into the community (Greenwald and Jack 2009, Wrigley 2013).

Another systematic and patient-centered model like the RED with similar components, e.g. multidisciplinary team and with focus on hospital care and discharge, is the Lund Integrated Medicines Management (LIMM) model conducted at a hospital in Sweden (Ghatnekar et al. 2013). It comprised a systematic medication review and reconciliation process from admission to discharge, also coordinated by a multidisciplinary team. The LIMM model aims to reduce drug-related readmissions and outpatient visits for older inpatients and has been proven to be cost-effective compared to standard care. In contrast to the RED care model, the LIMM model estimated the index admission direct intervention and total inpatient cost. Overall, the LIMM model reduced the care cost in hospital by EUR 340 allowing for a direct intervention cost of EUR 39.

The randomised controlled trial by Nikolaus et al. (1999) focused on continuous care within hospital and beyond with better flow of information between hospital and the primary care physician and appropriate discharge planning, similar to the RED strategy. The effectiveness of a comprehensive geriatric assessment alone and in combination with a post-discharge home intervention delivered by a multidisciplinary team was compared to usual care for older hospitalised patients. The comprehensive geriatric assessment, combined with the home intervention team, demonstrated a reduction in the length of index hospitalisations and subsequent readmissions, less immediate and delayed permanent nursing home placements and potential reduction in the direct cost of hospitalised older adults (as less days spent in hospital and nursing home) over 12 months follow-up from date of index hospital admission. Patients in the intervention group had a higher use of community services (e.g. meals on wheels) as they were better informed about such services. Such findings suggest that the base case analysis is conservative in assuming that direct RED costs are incremental, rather than substituting for other care costs arising during the index admission in current care models, and indeed also supports reduction in bed blocking with discharge focused care such as RED.

Considering this literature alongside RED, the key policy reforms required to achieve the expected benefits of the RED care model in over 65 populations presenting for hospital care with high prevalence of not being well-nourished are, to both (i) invest in better discharge care in hospital and (ii) allow system (particularly hospital to community care) flexibility to enable the expected downstream impacts in reducing rehospitalisation and aged care associated with higher engagement with primary and community care.

5.2 Strengths and limitations

A strength of this study is that it considered health effects and cost outcomes jointly when comparing usual care with an alternative strategy, in this case the proven RED discharge strategy, focused on continuity of care post hospital discharge. There are few health economic studies, like this one, that evaluate hospital strategies in older patients by considering the joint incremental health effects, costs and cost-effectiveness. The cost-effectiveness modelling study by Graves et al (2009) to reduce emergency hospital readmissions is an example that evaluated a comprehensive nursing and physiotherapy intervention in older patients admitted to an Australian hospital that was cost saving, improved health outcomes (i.e. quality adjusted life years) and had an almost AUD 8,000 net monetary benefit per individual offered the intervention compared to usual care for the 24-week follow-up. A further strength of the present study is that it also considered the joint incremental health effects and costs of the beyond hospital impacts of malnutrition to health system rehospitalisation and aged care need. This allowed for more appropriate coverage of impacts expected in aged populations (Middleton et al. 2001, Correia and Waitzberg 2003, Pirlich et al. 2006). Thus, the approach allows optimisation across the health and aged care system, as was modelled in the present study by applying the RED care model.

Advantages and disadvantages associated with modelled cost-effectiveness analysis depends on the quality, coverage and comparability of the model and its underlying data and synthesis. Models are simplifications of real life problems and are based on assumptions and have uncertainties. The probabilities used in the decision tree model were based on patient level data and the underlying population risk of malnutrition and survival. The MNA data was previously obtained using the validated and widely used MNA tool considered as gold-standard to assess nutritional status in older people. In contrast to most clinical trials with limited study length and follow-up due to constraint research budgets, the decision tree model utilised patient records with 12 months follow-up data. This allowed for sufficient coverage of health effects and resource use to capture the natural history use and relevant incremental effects, while allowing for treatment effect of care strategies when addressing hospital malnutrition in older adults. The model consequently enabled the translation of the RED treatment efficacy obtained from the RED RCT study by Jack et al. (2009) into conservative estimates of direct intervention and 12-month hospital resource use and costs for the base case. Additionally, it allowed for effectiveness (survival) and aged care use conditional on malnutrition status and the plausible impact of the RED care model on malnutrition status in sensitivity analysis.

An inherent limitation of this study relates to the retrospective patient data from 2009/2010, although further evidence makes it apparent that the patient population and clinical practice have not altered substantially since then. Data show a 30-40% malnutrition rate for inpatients assessed between 2011 and 2016 (unpublished data extracted from the hospital database by Bowden in May 2017) and reflects the 34% malnutrition rate in Charlton's study. Hence, a malnutrition baseline risk of the order of magnitude in Charlton's study continued across older patients in the same acute hospital setting.

The data are restricted to a single public hospital. However, only 3.3% (16) of the 481 older patients had admissions to other hospitals, reflecting that most patients prefer to return to the hospital closest to their homes, where their medical records are held and where they attend post-discharge outpatient clinics. In evaluating potential survival effects (i.e. sensitivity analysis in section 4.2.7), the study data did not record deaths that occurred outside the hospital in the 12- month follow-up period. Hence, there is a limitation in terms of coverage of patient deaths, which could lead to somewhat of an under- or overestimation of the relative survival rates between patients with malnutrition versus at risk of malnutrition versus well-nourished. Nevertheless, in that respect much higher aged care use of those with malnutrition compared to those at risk or well-nourished suggest that there may well be an underestimation of the overall survival benefit in avoiding being malnourished from that observed from in-hospital deaths alone. Another data limitation is that the clinical study, while controlling for primary MDC category on admission, did not obtain individual DRG data to better enable adjusting for multiple comorbidities that older patients can have. In that respect controlling for disease severity using a comorbidity index would also have been useful, as the greater the severity of the disease the greater is the likelihood of malnutrition or being at risk of malnutrition and of poorer health-related outcomes and related impacts of such morbidity and survival impacts on readmissions. Missing information on diet type and/or use of oral nutritional supplements may have also confounded the findings and should be considered in future studies.

The MNA data in Charlton's study were obtained on index admission, but MNA measurements were not repeated at the end of a patient's hospital stay. This information would have allowed assessment of improvement or deterioration of the patient's nutritional status associated with current practice. However, readmission and survival analysis both suggest that MNA at admission was highly predictive. Nevertheless, if MNA conducted at discharge a Markov model, organised around health states, here nutritional status, could have been constructed. Knowing the probabilities of transitioning between nutrition states with usual practice in hospital care could potentially have more accurately considered health effects, resource use, cost and cost-effectiveness of the RED care model relative to usual care when extrapolating over time beyond the study follow-up.

In terms of translating evidence, the RED study, from which the relative treatment effect on reduction in rehospitalisations was utilised, was undertaken in the US hospital setting. However, the relative treatment effect (30.4% 30-day rehospitalisation reduction) applied is considered as robust, while potentially conservative in the context of relative treatment effect. Similar applications of discharge models in other aged populations, have reduced rehospitalisations between 36% and 49.4% in later studies (Wrigley 2013; Markey et al 2013) and reduced index admission costs by a net EUR 340 allowing for a EUR 39 direct cost in the LIMM study (Ghatnekar et al. 2013).

5.3 Policy implications and further research

The RED care model is a hospital-to-home care transition program that is widely considered to be best practice as it has been shown in RCTs to reduce both hospital readmissions and total costs of care. An advocate, nurse or case manager is what RED model programs across RCTs have had in common and are key to enable optimised transition from hospital to home. There is a large potential for cost savings to the health system of the RED care model in addressing malnutrition and discharge/coordination of care issues for older adults within hospital and post hospital discharge over time. The present findings can be generalised to health care systems/models that have no appropriate discharge care planning and especially, no connection between hospital and primary care providers after hospital discharge to enable better post discharge care arrangements. The baseline risk of hospital malnutrition in a jurisdiction of interest, is either known or can be determined for the RED model of care to be implemented in a health care setting. Since introducing the “My Aged Care” by the Australian Government in July 2013, current care practice has moved further away from the RED care model. The policy of consumer directed care with the “My Aged Care” assumes that the patient can make informed decisions/choices on the services they need and who should provide those services, and that a market place of services exists for the patient to choose from (Australian Government, Department of Health, Ageing and Aged Care 2018).

However, optimising the positive health and aged care system costs of care benefits of re-engineered discharge in aged patients requires health system quality of care measures that encourage small investment in discharge processes, as well as shifting some resources over time from hospitals into general practice and community care to enable better population care for nutrition and more generally. To achieve this, payment models for care that are not purely admission-based are needed, that allow for health system care quality and avoid cost- and effect-shifting incentives.

Mandatory malnutrition screening for hospitals, and financial incentives when doing so, could motivate hospitals to implement a cost-effective hospital care and discharge model like RED, where timely identification and treatment of malnutrition would be an integral part of patient care. In evaluating program interventions and policies and efficiency of performance of hospital providers in practice, Eckermann (2004, 2017) and Eckermann and Coelli (2013) point to the necessity of allowing for health system downstream health effect and cost impacts. They argue that this is required in order to avoid perverse incentives for cost-shifting (i.e. increased need for health care post-discharge) and effect-shifting (i.e. expected negative effects on health outcomes beyond discharge). The net benefit correspondence theorem (NBCT) is the only method that allows the inclusion of quality efficiency measures consistent with the appropriate objective of maximising net benefit underlying evidence based medicine. Furthermore, coverage (adequate scope and duration), comparability (incremental relative quality/cost impact) and consistency (joint analysis of incremental costs and effects by controlling for all risk factors when estimating the risk difference and translating to a jurisdiction of interest for generalisability), are the key decision analytic principles of the NBCT and for a robust cost-effectiveness analysis. It provides a robust framework to prevent cost-shifting and cream-skimming incentives and creates appropriate incentives for net benefit maximisation in the health care and related systems (e.g. aged care) across time (Eckermann 2017).

In recent years the health care systems and policy makers have turned their attention to providing high quality and affordable patient care with a multidisciplinary team approach

(Tappenden et al. 2013). It has been recognised that nutrition care plays a critical role in this process and especially in addressing hospital malnutrition in older patients. Tappenden and colleagues (2013) proposed a care model, in line with some of the principles of the RED care model, to improve adult hospital malnutrition both within hospital and in the post-discharge setting. They developed six principles, namely, 1) creating a hospital culture that understands the value of nutrition, 2) redefine hospital staff roles to include management of nutrition, 3) strategies to identify all patients that are malnourished and at risk, 4) immediate intervention with comprehensive nutrition care and continued monitoring, 5) communicate nutrition care and 6) develop a comprehensive discharge nutrition care and education plan. Other authors, like Loeser (2010) and Lim et al. (2013), agree on the point that multidisciplinary nutritional support teams consisting of doctors, dietitians, nurses and other health care staff with knowledge about the value of nutrition are required in hospitals to practice evidence-based nutritional medicine. A nutrition support team with its structure and functions can work in a clinically and financially efficient way given that higher payments are received for DRGs incorporating malnutrition (Shang et al. 2005, Rasmussen et al. 2006, Kennedy and Nightingale 2005, Scott et al. 2006, Loeser 2010). While Tappenden et al. (2013) have not applied their proposed principles, Jack et al. (2009) have proven the success of their RED principles, while without a specific nutrition focus. The general RED principles that focus on discharge and appropriate downstream care are likely to be even more appropriate in the older patient population presenting with or at risk of malnutrition in hospital, given the importance of continued nutrition care at and after discharge. Factors that are key to a successful implementation of such an integrated care model include coordination between a discharge planner and a multidisciplinary team, as well as a timely identification of malnutrition with better coordination, education and access to appropriate care within hospital and in the community. An important task for establishing the RED care model is to convince the hospital management of its economic as well as health importance. Tailored and personalised nutritional support is not only part of primary health care, but should also be seen as an integral and efficient component of medical therapy and disease prevention in the hospital setting (Loeser 2015).

Aside from reducing rehospitalisation rates and addressing malnutrition status of older hospitalised patients that are malnourished (32.2%) and at risk (54.5%), the RED care model is expected to aid in diagnosing nutrition and wider care needs. In the current older cohort where 86% were classified as poorly nourished, nutrition screening seems secondary to considering care needs across all. However, given that the health benefits (i.e. improvement in nutritional status, survival) and the cost impacts on hospital/aged care become quite significant for malnourished as well as for at risk older patients, it is recommended that all patients aged 65 years and older at admission be diagnosed and extra services offered to those identified as being malnourished. The at risk group would also benefit from nutrition care planning and/or monitoring as part of the RED strategy. The RED care model can enable continuity of care with wider community/primary care providers, for routine screening and monitoring of malnutrition in primary care (Hamirudin et al. 2014) or in residential aged care facilities. Screening all older patients is challenging in hospital as dietitians struggle with the increase in dietetic referrals for nutrition assessments in the older population. The value of nutrition screening lies in directing and allocating the scarce dietetic and care assessment resources.

Considering the current nutrition screening options for geriatric acute care in this thesis (chapter 4, section 4.2.1, Fig. 4.4 inverted decision tree), highlights the MNA-SF as the preferred screening tool over the MST. Despite a perception that the MST is more suitable to apply in acute care inpatients and its high specificity (88%), in older patients, relative cost savings of about AUD 1,500 were estimated with the MNA-SF (100% sensitivity and 39% specificity, Neelemaat et al. 2011) compared to MST (74% sensitivity, 88% specificity, Neelemaat et al. 2011). That is, when considering in-hospital and downstream aged care costs of a population presenting in hospital in which 86% are malnourished or at risk, and only 14% are well-nourished and potentially at risk of becoming overnourished. In relation to be overnourished, research by Kent and colleagues reported that 1.1 million older women in the UK were overweight and obese and had higher costs associated with it (Kent et al. 2017, section 1.1, Fig. 1.2). Overnutrition just like undernutrition has adverse consequences for health effects and nutrition and lifestyle post discharge leading to costs in hospital and downstream care.

Clinical studies often neglect the wider socio-economic implications that can lead to changes in diet, mental health and behaviour in older adults; they typically focus only on nutrition interventions and associated medical costs. Social determinants of care such as living arrangements, social interaction, isolation/loneliness, mood, understanding of medications, pain management, financial constraints, hospital communication, PCP involvement and transportation and access to care can be key for an older person's recovery. Given lifestyle, environmental/social and risk factors in hospital, at home or in other post-discharge settings, it is particularly important for an older person to have access to appropriate optimal nutrition in hospital and beyond. Thus, providing in-hospital patient-centred education, as suggested by the RED care model, including nutritional care, eating in pleasant surroundings with good company, encouraging physical activity between meals and minimising the risk based on social determinants, have been shown to promote health in the ageing population. Nutritional care plans can then often best be reinforced by the PCP, whilst recognising that the primary carer, who can also be a family member for those discharged home or a residential aged care worker for those going into aged care, is likely in a better position than a dietitian to manage the older person's dietary requirement in the community. The RED care model facilitates engagement with the GP and a variety of other health care services. Visualisations of linked health data (e.g. hospital admissions, GP visits and other health events), as recently employed by Falster et al. (2016), would be valuable in a prospective study to check expected modelled health service use and to aid in RED performance monitoring.

There is growing evidence for the quality of nutrition and for nutritional medicine as an important factor in both physical and mental wellbeing (Sarris et al. 2015). Depression or other mental illnesses that are common in older people, can be influenced by changes in diet and exercise. The body needs to be properly nourished in order to prevent diseases and for older people to be able to stay physically, socially and mentally active. It is also the case with care of the older people particularly that isolation and loneliness are major risk factors for malnutrition in older patients presenting to hospital (Porter Starr et al. 2015). Living arrangements, environment and wider community are especially key for older adults with dementia to successfully age and live in their community of choice (Kalache 2013). Key to such active and successful ageing are health promotion prevention strategies that engage with community networks. Consideration of community integration and lifestyle preferences have been shown to be key in the long-term success of health promotion and disease prevention strategies (Hawe and Ghali 2008, Shiell et al. 2008). This might also be important for successfully implementing RED into the hospital and translating it into the community.

Building social capital (i.e. participation of community, friends and/or family) as one of the four pillars in Kalache's WHO 'Active Ageing Policy Framework' (2013), alongside health capital, security (financial capital and/or resilience) and life-long learning (education capital), enables the community to remain involved, have ownership and expand long-term impact of community. Eckermann (2017) emphasises the importance of aged and dementia populations remaining physically, mentally and socially active in age- and dementia-friendly communities, such as the dementia-friendly community model developed in Kiama in NSW, Australia (Phillipson et al. 2016). Similar aged care facility examples include Hammond care in Australia, memory care facilities and guidelines in the US (Zeisel et al. 2003) and a dementia village 'The Hogewey' which is a gated model village in Weesp, Netherlands (Fernandes 2012). Age- and dementia-friendly communities provide a more supportive environmental framework for improved dietary behaviours in older persons considered to be poorly nourished. As Alexandre Kalache indicates, with the baby boomer cohort (born 1946-1964) entering older age, there is a key challenge and opportunity now to support and implement policies for successful ageing, such as health promotion and education as well as whole of government approaches, like age- and dementia-friendly communities in addressing the longevity revolution.

The RED care model for older patients in-hospital with malnutrition is likely to provide appropriate access to and better quality of primary health care in the hospital and beyond. The RED care model moves toward offering better integrated care in chronic disease and malnutrition management in older adults linking hospitals, PCPs and allied health services in community and aged care. Promotion of successful ageing in older populations is undoubtedly essential, the analyses presented in this thesis has shown that the RED care model approach, in better integrating acute and post-acute community and aged care, would result in expected cost savings to hospital care over time (related to rehospitalisation in conservative base case and in previous literature pointing to index admission cost reductions and avoiding bed blocking). There are also high level aged care system cost savings expected by avoiding residential aged care for the older patient population with or at risk of malnutrition, as shown in sensitivity analysis. While successfully addressing malnutrition care within integration of in-hospital and post-discharge health and community services for older persons, the RED care model can also aid in creating age-friendly care and communities.

6 CONCLUSION

In the context of baby boomer populations ageing, together with constrained health and aged care budgets in countries such as Australia, higher quality, affordable healthcare strategies and policies for successful ageing are required.

This thesis has focused on strategies for addressing malnutrition amongst hospitalised older patients, given analysis of downstream health and aged care outcomes and costs. The RED hospital and discharge care model developed by Jack and colleagues (2009) has been shown, with cost-effectiveness analysis informed by the evidence synthesis as presented in this thesis, to represent a cost-effective strategy in addressing patient care needs, while also reducing downstream health and aged care costs. The RED care model appropriately recognises hospital malnutrition and promotes the role of integrated nutrition care for older patients across hospital, home, community and aged care settings. Nutritional status is a good marker for the level of care in the community post hospital separation. Receiving the right nutrition-related care that is commenced in hospital and continued in the community, for example through primary care General Practices, enables RED to have a system-wide effect. The RED strategy, through its evidence-based principles helps to navigate patients with their care needs through the hospital care and discharge process. The RED discharge nurse advocate is of central importance in this systematic and coordinated care model. RED is expected to improve an individuals' quality of life by increasing communication of information to and use of PCP care and reducing unnecessary hospital readmissions, and aged care service use, thereby significantly reducing overall care costs. The RED care model is expected to aid in the continuity of care with the wider community/GP and where necessary in aged care. Most of the current models/policies fail with fragmented and disjointed in-hospital medical and nutrition care and discharge procedures as well as lack integrated links between hospital and PCPs in community and aged care.

Improvements to patient health outcomes and lower health system costs in the acute geriatric hospital setting have been documented if malnutrition is identified, treated, monitored and reported in a timely and correct manner. The reality, however, is that nutrition screening for all admitted patients, as stated in the nutrition care policy released in 2017 by NSW Health (Agency for Clinical Innovation, NSW Government 2017), is currently reflected in poor compliance that is not routinely acted upon. Given the high prevalence of older inpatients being malnourished or at risk as shown in Charlton's clinical data (2013) and the consequent higher associated health and aged care needs and costs, a strong case can be made for a dedicated focus on nutrition assessment in older patients. Ideally such assessment should be part of a quality of hospital care measure, and revisiting ways to improve compliance should be high on hospital strategic agendas. In this respect, the MNA-SF has been shown to be a valuable assessment tool in allocating scarce dietetic/care assessment resources in hospital nutrition and dietetics departments that are often underfunded.

Health economics advice need to take a big picture perspective of the health policy impacts, allowing for system-wide health effects and costs. Public provision health systems such as Medicare with universal access to necessary care have been shown to be more effective and efficient, as well as equitable, based on strong evidence internationally (OECD 2013, Davis 2014). However, systems are going to face, and are already facing, challenges with the ageing population and require system reform to enable successful baby boomer ageing without severe budgetary shortages. More needs to be done to facilitate self- and informal care in the community and investment is required into programs for older adults that integrate care across the health system by linking acute and GP/community care in particular (Jack et al. 2009, Kalache 2013, Phillipson 2016, Falster et al. 2016, Swerissen and Duckett 2016, Eckermann 2017).

The RED care model is a complex intervention with many components and outcomes. Its effectiveness in terms of benefits, based on the underlying strengths and limitations of the clinical and health economic data, have only been considered in the sensitivity analyses around a very conservative base case. However, the RED care model has high potential to work in the older Australian hospital population. Further nutrition and health economics research for utilising and optimising this care model is warranted, particularly in acute geriatric hospital care, with a strong focus on nutritional medicine, which Sarris and colleagues (2015) consider to be an important factor in improving mental as well as physical health. Nutrition is a marker for the ability to meet care needs and prevent social isolation, both of which contribute to an older person's physical, mental and social health. Apart from appropriately allowing for social determinants in care arrangements, cost-effectiveness findings in chapter 4 and discussion of policy implications in chapter 5 of this thesis highlight the need to implement the RED care model in older patients presenting in hospital who at risk of or with malnutrition. This will (i) enable the discharge planner to appropriately coordinate discharge care needs and (ii) allow for system incentives and resource flexibility (particularly hospital to community care) with expected downstream impacts to reduce rehospitalisation and aged care service use, while higher engagement with primary/community care. Creating appropriate health system incentives for (ii) in practice requires payment models for care that are not purely admission-based, but rather based on performance measures and that are set up to include payment models that encourage downstream population health system care. It would also require consideration of quality that is consistent with system-wide cost-effectiveness (net benefit maximisation) and prevent incentives for cost-shifting and cream-skimming, that the net benefit correspondence theorem allow (Eckermann and Coelli 2013, Eckermann 2004, 2017).

The RED care model and a payment model with appropriate incentives are key for health and wider health and aged care system optimisation to improve system quality and, particularly, to address the burden of malnutrition in hospitalised older adults. Care models such as RED can more generally be seen as better enabling populations to age successfully within their community of choice. In that respect, the long-term success of RED as a hospital malnutrition and chronic disease prevention strategy depends on engagement with community/social networks as part of social capital building, as outlined in Kalache's WHO 'Active Ageing Policy Framework' (2013). It can further strengthen the development of more age-friendly communities and care (Phillipson et al. 2016).

In summary, it can be concluded that a systematic and comprehensive RED hospital care and discharge strategy allows a model for appropriately integrated nutritional and wider care, with associated expected survival and aged care benefits, as well as cost reductions within hospital and aged care. In terms of wider policy implications, the RED care model aids in assessing both nutritional and wider care needs and in improving mental as well as physical health and in enabling and encouraging older people to remain socially active. The RED care model provides an appropriate hospital based conduit to better integrated care in the community by improving health and nutrition care pathways with appropriate care in community which in turn reduces the need for aged care as well as further hospital services. The optimal implementation of a better in-hospital, discharge and post-discharge care integration with the RED care model, informs highly policy relevant emerging debates about cost-effective strategies for health and community prevention and aged population care pathways and needs assessment for older patients with malnutrition presenting in hospital. Malnutrition in the older hospital population is a good indicator of older adult care needs and relationships in the community. Earlier identification of malnutrition and appropriate care arrangement in hospital settings extending into the community with care models such as RED can lead to improved processes for successful ageing in the community. It can prevent aged care needs as well as appropriately identify the care needs where relevant in aged care.

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